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HUMAN FACTORS OF CC-130 OPERATIONS

FINAL CONTRACTOR'S REPORT:

TRAINING SYSTEMS KNOWLEDGE

W7711-5-7264/001/TOS

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Executive Summary

This report details work conducted under the auspices of the DCIEM/ATG Human Factors Study of CC-130 Operations, Phase II. The contractor was part of the Crew Behaviour Assessment Group (CBAG) in Phase 1, which was charged with developing a measurement tool for assessing flightdeck behaviours indicative of safe flight behaviours. This final report first outlines the scope of the contract work conducted on a continuing basis in support of the Phase 1 objectives during the time this second contract was in place. In addition, and mainly, this contract was let in order to further one of the recommendations of the Phase 1 report, namely that Air Transport Group (ATG) consider improvements to their training system in the area of aircraft systems knowledge. This final report therefore summarises the goals, nature and scope of that work, includes as an appendix the substantive report on training recommendations (in the form of a fully costed proposal for training improvements), and makes further observations and recommendations for the way ahead in systems training. Information sources, influences, and contacts are listed to aid those continuing with this training revision effort.

Contents

Introduction: The CC-130 Human Factors Project

The current contract was let in the context of beginning the second phase of the CC-130 Human Factors Project, though it also contributed to on-going taskings mandated within the first phase. In order to summarise the history of the project to date, and thereby provide a context for summarising the work conducted under this contract, consider this quote from the final Project report authored by Hendy et al. (1998, p. ii):

"In January 1994, the Defence and Civil Institute of Environmental Medicine (DCIEM) was tasked by Air Command (AIRCOM) to study human factors issues in CC-130 Hercules operations within what was then Air Transport Group (ATG) — now a component of 1 Canadian Air Division. This tasking reflected a perception that the accident record within the Canadian Forces (CF) fleet was significantly worse than the record of other fleets involved in similar operations. In response to this tasking, a joint DCIEM/ATG team was formed. The activities of this study group were funded by the Chief of Research and Development (CRAD).

The first activities of the team involved a review of relevant literature, a survey of Squadron attitudes regarding the priority of operations, and an examination of CC-130 accident boards. The CC-130 Hercules entered service with Air Transport Group in 1960. Prior to 1980 there had been two A Category accidents within the fleet. Since 1980 there have been six major accidents with the destruction of seven aircraft and the loss of 44 lives. No common cause factors were apparent in the board findings that would suggest that the same set of deficiencies were acting in these accidents, although human factors issues were implicated in all.

At the outset, the study team decided to take an approach to this tasking based on controlled experiment and field observations. Through an empirical approach it was hoped to present objective data that would define the extent of any problems identified, and provide a bench mark against which various interventions (e.g., effects of experience level, fatigue, training) could be assessed with regard to their eventual contribution to improved safe flight performance. To this end, the team assembled two working groups with the following responsibilities:

> *Crew Behaviour Assessment Group (CBAG) — to develop and validate a battery of behaviourally-based measures that could be used to distinguish between those behaviours indicative of safe flight performance and those that are not.*

> *Flight Performance Assessment Group (FPAG) — to develop and validate a battery of measures based on aircraft status and flight path that could be used to detect departures from safe flight performance.*

There have been two Phases to this study to date, with a third Phase to follow. In Phase I (January 94 to July 96) the two working groups attempted to develop and validate their measurement batteries. During this phase a number of observations were made that led to certain recommendations being made to ATG for changes to the training system. In Phase II the requirements for implementing these changes were explored and a costed proposal was put to ATG in June 1997. The completion of the Phase II activities marked the end of the study group's mandate under the terms of the original tasking."

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Goals of the Contract

The contract goals originally centred on the empirical thrust of the Phase 1 mandate: to develop a set of observational and evaluative metrics of human flight performance that could serve as a tool for measuring the effects of various factors, and later interventions, thought to relate to the safety of CC-130 flight operations. While the CBAG's work in Phase 1 was designed as but a first step, a measurement development and validation stage for the tool, the controlled series of full-motion simulator (SIM) sessions that were conducted and analysed led to some results that ATG found interesting and telling. Among these was an apparent lack among some – especially inexperienced – crews of basic aircraft systems knowledge.

The belief held among DCIEM and ATG that these knowledge deficits should be ameliorated immediately, led to a change in focus of the contract as originally conceived, a change away from empirical investigations using the human performance metrics and toward recommendations for implementing training solutions that would redress the systems knowledge problem.

In addition to these foci on:
1) completing the Phase 1 data base construction and furthering analysis of it in order to more fully develop and validate a crew performance metric; as well as,
2) making recommendations for improved systems knowledge acquisition training; an additional focus was on
3) being available as a general SME resource for consultation with various principle or supporting investigators working on the Project's other aspects.

I now review the scope and methods of work for each of these elements, listing literatures, contacts, and resources (typically the result of conference attendance and networking) for each along the way.

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Scope and Methods of Work

Crew Resource Management

Creation of A Unique Data Base

The current contract began during the latter stages of the first phase of the project, with an intent to examine empirically the human factors thought to contribute to the assumed lowered flight safety standards in the CC-130 fleet. These lowered standards were presumed to have led to the recent poor accident record. To that end, the initial work covered under the contract involved, in part, a continued focus on building an empirical data base and a defensible tool for assessing human flightdeck performance — at both the individual and team levels of analysis. This culminated in a completed database from the Phase 1 validation study of the CBAG. It will be recalled that only the data collection was covered by the prior contract. Final coding, analysis, interpretation, and preparation and presentation of results were covered by the present contract.

In particular, thanks to the work of Dr. Megan Thompson, who largely supervised the effort on a sub-contractual basis, the complete set of 23 CC-130 crew simulator (SIM) sessions is now available as a resource for analysis by DCIEM scientists. Scientists external to DCIEM will have to wait to use the resource until the ethically required step of securing permission from the individuals involved to have their sessions viewed and analysed is finished. This permission is necessitated because of the promise of confidentiality made during the study to flight crew personnel. The confidentiality assurances were needed to ensure high participation rates of crewmembers and to reassure them that their participation was under conditions of "no jeopardy" to their careers. (Indeed, the negative reaction and objections of one aircraft commander who inadvertently discovered that ATG personnel had judged his performance as recorded on the videotapes bolsters the argument that gaining such permissions is crucial; it took a considerable effort from our team to assuage his concerns).

The CBAG's Phase 1 report of the validation stage of metric development (Banks et al., 1997), completed during the present contract, was based on the data from just 12 of the 23 crews observed under controlled SIM conditions — those six crews judged most proficient and those six judged least. This analysis proved complex and time-consuming. It involved such steps as the multiple viewing of videotapes leading up to the development of the coding scheme, articulation of categories, multiple-judge coding of the tapes for reliability analysis, re-articulation of the coding categories, performance rating made by three independent pilots invited to DCIEM for viewing the tapes, selection of extreme groups for construct validation, and so forth. Results for this stage are reported in Thompson, Jamieson, and Hendy (1997).

Under the purview of the present contract, this initial work was further extended. First, naïve coders were trained in the categorisation scheme. Because of the degree of effort required to view and exhaustively code each tape, and the unavailability of suitably expert resources to be devoted to carry out this task, this painstaking stage was conducted by several trained observers

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who were not pilots (some supported by this contract, others not, for example, DCIEM summer student interns). While this undoubtedly added to the time taken to perform the coding, it also suggests that non-experts may be employed in such analyses successfully in future after suitable familiarisation and training.

To complete the full database analyses, all 23 crew tapes were copied (for safekeeping and security), and fully transcribed (a step not undertaken in the Phase 1 analysis of even the 12 data points retained). One set of tapes was time-stamped for later temporal analysis (that analysis, conducted by Dr. Thompson, and reported in the Phase 2 report under Thompson (1998), was not covered under the terms of this contract; the results have also been submitted for publication, Thompson, Jamieson, & Hendy, 1999). Multiple coders then coded crew behaviour into the behavioural typologies developed (for details see Banks et al., 1997; and Thompson et al., 1997; the final behavioural metric completed under the contract is presented in Appendix A).

The entire process took hundreds of hours of sub-contractor and contractor time to complete, but eventuated in a unique resource — a data base of 23 fully transcribed simulator missions run under controlled scientific, rather than training, conditions in an event-based scenario (cf., Lauber & Foushee, 1981; Prince, Oser, Salas, & Woodruff, 1993; Seamster, Hammond, & Edens, 1995). The design of the scenario, geared toward creating more naturalistic conditions of decision making, captaincy, and crew performance, complete with inter-related system causality in terms of aircraft systems failures, serves as a valuable analytic and anecdotal resource for CC-130 crew performance and operations, as well as more generally for team performance on the flightdeck of multi-place aircraft. Its future further analysis holds the promise of revealing, at least on a descriptive basis, the correlates of safe and proficient flight performance, as exemplified in the "best-performing" crews (i.e., as independently, and "objectively" judged by check airmen). It is hoped that such future analysis of this set of time-stamped, transcribed, and typologised missions will yield further clues as to the individual and team behavioural profiles of flightdeck performance excellence.

Where to go to find the database: Consult with Dr. Megan Thompson, now a DS at DCIEM, under whose watchful eyes are kept the physical tapes, as well as the transcriptions and coding masters and results.

Validation Study Report, Presentations, and Paper

After Dr. Thompson was hired by DCIEM as a DS in November of 1996, I worked with her in analysing and preparing the validation study report that was included as part of the Banks et al. (1996) report on Phase 1. Results were presented as part of a daylong presentation at DCIEM, as well as a report to the Commander, 8 Wing. Also under the purview of the contract were Dr. Thompson's briefings to the squadrons about the results of the study.

In addition, another version of the Phase 1 results was communicated at the International Symposium on Aviation Psychology in April of 1997. I contributed to both the abstract that was accepted for presentation at that Symposium (which was submitted while Dr. Thompson was still part of the contract team), as well as the subsequent write-up, on which Dr. Thompson led the way (Thompson, Jamieson, and Hendy, 1997).

Keeping Abreast of CRM Issues

Throughout the course of this work, Drs. Thompson and Jamieson kept abreast of developing issues in CRM both in general and at ATG. This included such activities as reading and incorporating ideas from such sources as:

- the literature on team performance;
- the net-based CRM discussion group and developers forum (crm-devel@db.erau.edu);
- a recent volume on naturalistic decision-making (Zsambok & Klein, 1997).

The fruits of this labour and thinking is to be found in the revised version of the contractor's final report on Phase 1 of the Project, where the literature review on CRM issues is updated from the original draft report of March 1995 (see Jamieson, 1999).

In addition to these sources, much useful information was garnered at the International Symposium on Aviation Psychology, as there were many presentations and workshops pertinent to CRM issues. Conference notes from Workshops attended are attached as Appendix B. As one example, note the high degree of integration of human factors teaching in all aspects of flight training as presented by Wiggins and Henley in their workshop (materials are entitled: "Integrating Human Factors into a Flight Training Syllabus"). In this workshop they argue for the need to teach human factors throughout training, a view that presages the CRM course revision submitted by Keith Hendy as part of this contract work (Hendy & Ho, 1998).

Finally, in March of 1997 the contractor attended, with a large contingent from DCIEM, ATG's two-day course on CRM entitled Aircrew Co-ordination Training (ACT). Notes and observations from this course are attached as Appendix C. Subsequent to this course attendance, the contractor focused almost exclusively on the systems knowledge acquisition aspect of the scope of work, leaving the development of a suggested revision to ACT training to the contract's scientific advisor, Keith Hendy. While keeping abreast of all written materials, my contributions in this area after that time were small. Mr. Hendy and Dr. Thompson took over that part of the substantive work, with Dr. Thompson focusing on issues of creating a proposal to demonstrate via evaluative research the efficacy of any CRM course changes proposed.

Systems Knowledge Acquisition

The CBAG study findings, as alluded to above, led to the recommendation that certain modifications to the training system be made right away (i.e., not waiting for the results of further empirical investigations using the Phase 1 human metric tool). These included the directive to modernise the learning processes by which systems knowledge is acquired. This directive served as the main focus of the contract. The main product of this element (Jamieson,

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1998) was my contribution to the final Study report — Volume 4 of Hendy et al. (1998) — which is attached as Appendix E.

Sources of Information

The Volume on systems knowledge acquisition is the synthesis of many information sources. While it is a re-iteration of materials contained in Jamieson (1998), it is useful to list down several of these many sources:

- ATG systems knowledge training course materials;
- ATG-provided general materials on CBT, use of distance based education, etc.;
- Hypher's report on CC-130 training modernisation;
- Conversations with ATG training personnel at various levels;
- Conversations with Smart Board training module developers at Warner Lambert;
- Conversation with CFB Edmonton staff re: the AUP;
- Conversations with Flight Safety International personnel;
- Literatures on: intelligent tutors, case-based and problem-based teaching, self-directed learning, distance education, life-long learning, risk assessment, etc.;
- Conversations with individuals met at the Society for Applied Learning Technologies conference on interactive multimedia;
- Attendance at the Society for Applied Learning Technologies 1996 Interactive Multimedia Conference;
- Attendance at the Industrial Technology Research Centre (ITRC, University of Waterloo) conference on on-line learning.

All of the ATG-provided materials are being returned to DCIEM. Photocopies of the most relevant articles from the literature reviews are also being submitted. Neither of these batches of materials is included in the Appendices of the present document.

A copy of the SALT conference proceedings is provided, and my notes from that meeting are found filed in the well-organised binder from that meeting. A summary of the most pertinent presentations is appended as an Appendix to the Volume 4 substantive report (Jamieson, 1998)..

The ITRC Symposium materials and my notes are appended as Appendix D.

Below is a sampling of particular individuals whose contributions to my thinking were influential, or who would serve as valuable contacts for anyone continuing this work.

Contacts

Name	Affiliation	Topic Area	Learnings
Maj. Dan Duggan	ATG	Overall training philosophy/resources	Distribution of training
Maj. Rick Lukes	ATG	Systems training	CBI; Smart Boards; 426 hardware infrastructure
Lt. Col. Peter Thorpe-Levitt	ATG	Training and development	New methods, Hypher report, etc.
Sgt. Dave Pollard	ATG	Hydraulics instructor	How module designed, integration with in-class methods
Maj. Pierre Naud	ATG: Chief Technical Instructor	Adaptation of smart board lessons for pilots	Using low/high fidelity short-cuts to Smart Boards for pilots; Organisational resistance to DCIEM authored "fixes"
Brad Waddell	Flight Safety Canada / Flight Safety International	Intelligent tutoring systems	FSI review leading to questioned efficacy of intelligent tutoring systems
Martin Smith	Aviation Human Science	Situation Awareness	Phenomenology of situational awareness
Richard Pappas	Lambert Multimedia 514-322-0630	Smart Board system simulators	SmartBoard Software architecture, potential upgrades, costs
Robert C. Hughes	Cubic Applications	Team performance simulations; after action review as training aid	Metacognitive development in training
Elias Awad	Exsys	Expert systems software for knowledge extraction	Org. knowledge dump of experts on particular systems
Alan Blizzard	McMaster University Instructional Development Office	Case-based teaching	Feasibility of this approach to ab initio, AQP training

General Consulting to OPIs/ATG

In addition to the focus on CRM and knowledge training, there were several other contributions to the CC-130 Study made by the contractor, and supported by the contract, that leveraged my involvement in the project from Phase 1 and contributed to my subsequent development as a SME in the area. These included:

- availability as a general consulting resource on matters of operational logistics, strategy and experimental design for OPIs planning studies within the scope of the Project; and
- liaison and consultant on the captaincy study.

I played a minor role, with Dr. Thompson, in helping to design and position, for ATG acceptance, a study of fixed and formed crews to be led by Cpt. Helen Wright. Maj. John Latullipe (8 Wing) was part of those consultations. However, the study did not receive approval to proceed.

In addition, I also played a very minor role in the conceptualisation of a study of aircrew fatigue on long-haul flight operations to Bosnia, led by Michel Paul (Paul, Pigeau, & Weinberg, 1998).

I had somewhat more of a role in the study on Captaincy conducted by Ghee Ho, a York university graduate student in psychology, who is conducting his research under the guidance of Keith Hendy. The study asks ATG CC-130 Hercules aircrew, of all positions, to "fill out" a computer-assisted personal interview (CAPI) regarding their conceptions of good versus poor captaincy. Here, I provided some conceptual input in the design stage of the Personal Construct Theory technique of eliciting constructs, as well as some advice on developing dependent measures (indicators, actually, since this was a correlational study). Mainly, I helped provide some liaison with ATG personnel at 8 Wing to get the study going (i.e., gaining acceptance, establishing essential contact personnel, etc.), accompanying Ghee on a trip to Trenton. I would recommend an investigation of recent advances in categorical data analysis and graphical presentation (as contained, for example in SPSS v9.0) as another way to analyse the data beyond those analysis methods thus far proposed to be used in the study.

Future Directions: The Way Ahead for Training CRM and Systems Knowledge

It is my belief that a concerted effort needs to be made to monitor and evaluate the state of aircraft systems knowledge and CRM within the Hercules community post-ground school and post-continuance training. In addition, this needs to be done both squadron- and fleet-wide, and on a continuing basis. I have reviewed in Volume 4 of the final Project report (Jamieson, 1998) the need and opportunity to develop pilot-targeted case-based lessons and scenarios using the Smart Boards as a basic element, and then distributing these to the squadrons for either self-study or facilitator-led training. This training distribution to optimise the conveyance of concepts at 426 and skill at the squadrons in the realm of systems knowledge can be logically applied as well to CRM training. The next step in the training evolution sequence for both areas is nearly at hand.

After the publication of the Volume 4 report and recommendations, authors, scholars, and research investigators have published relevant materials on the topics inherent in training systems knowledge (or CRM or any other topic for that matter). I have submitted (though not as Appendices due to their extensiveness) two additional documents: a recent (March 24, 1999) search for articles on simulation in training that may be valuable to those carrying forward on these training recommendations, and a current (March 25, 1999) listing of companies providing aeronautic services — software and hardware, training, etc.

Beyond these most recent sources, we have to look no further than the published proceedings of the 9th Bi-Annual International Symposium on Aviation Psychology (all references are 1997) to find evidence of active authorship and research in many of the new conceptual teaching and learning areas cited in Jamieson (1998) concerning:

- Piagetian concepts of accommodation and assimilation (Witiw)
- Principles of andragogy (vs. pedagogy) and engaged life long learning (Harris & Conrad)
- Self-directed and problem-based learning (Hill)
- Developing self-awareness, self-critiquing and metacognitive skills (Anderson & Henley)
- Aeronautical decision-making and situation assessment using PC-based trainers (Barber; Jentsch, Irvin, & Bowers)
- PC-based aviation training devices (PCATDs) (Emanuel; Phillips et al.; Talleur et al.; Talyor et al.)
- Balancing ground school with OTJ (Mattoon)
- Use of videos (Shaffer)

This year's 10th Bi-Annual International Symposium (May 1999) promises new developments as well, if the breadth and depth of topics to be explored as indicated in advance Symposium announcement literature and workshop line-ups are a reliable indication.

Finally, recent advances in web-based software now allow for the running of simulation groups over the internet. In this paradigm, flight crews can be constituted from distant physical locales,

and can be brought together for scenario sessions executed in real time. While the intent would not be a high fidelity representation of flight systems (though that too will be possible soon enough), the kinds of crew captaincy and decision making skills, crew resource management skills, as well as systems knowledge inter-relations that have been the focus of the contract work can be tested. Mid- or low-fidelity event-based scenarios that teach higher order cognitive skills and task and teamwork skills can be mounted with relatively few technical challenges.

The contractor is currently helping to develop a group-at-a-distance type of simulation scenario to be deployed on a web-site now under construction (the site is currently up and running as 'www.scenario.competitor.com'; it is worth a visit to see some state-of-the-art functionality in interactive web design). Members of the intended group will be brought together in real time and asked to play, as a group, our event-based scenario simulation. Though the focus is on democratic groups rather than teamwork, the design principles, functionality and potential are similar to what might be rolled out for the Hercules community. Regular role plays of this type, which intermix squadrons in the constitution of their crews, will allow uniform norms and implicit safe flight behavioural standards to develop more quickly fleet-wide. And, of course, squadron-specific operational requirements can also be the focus.

The work is being conducted as part of a consortium, but principle contacts of value to this project include:

1. Peter Warrian, President, Environics Technologies Incorporated, a specialist in organisational knowledge retention, assessment and development; and
2. Ken K. Campbell, President, Competitor Communications Incorporated, a web-design company (Ken is a regular contributor to the Star's weekly Thursday section on emerging technologies, Fast Forward, and former programmer with experience in military simulation).

Conclusions

Technological advancements in training delivery software have now reached the point where self-directed, problem-based learning can be considered anew as a primary method of training aircraft systems knowledge via computer-based training. Sound principles of andragogy must provide a basis for the construction of a repertoire of training cases that imparts strong conceptual knowledge at 426 Squadron and continues its development with examples to be assimilated during OJT. Such distributed, just-in-time training, with a phased delivery like that envisioned, will put extra demands upon, but also further reinforce the value of, staff trainers.

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Acknowledgements

Appendices

For the purposes of minimising reproduction costs and volume, the following materials often summarise, but do not include, the materials carried back from conferences and meetings. However, single copies of these materials are being submitted with the Contractor's Final Report.

Appendix A: Revised Crew Behaviour Scheme

On the following pages is a description of the final, revised crew performance metric as developed under this contract. Recall that a central construct was the shared mental model and that these observable metrics focused primarily on the verbal cockpit communications of aircrew as indexing the presence of these (directly unobservable) mental models.

Mental Model Coding Categories

NOTE: A COMMUNICATION MAY BE CODED WITH MORE THAN ONE MENTAL MODEL DOMAINS AND FUNCTION

CONTENT DOMAIN OF COMMUNICATION	CODE	DESCRIPTION	EXAMPLES
MISSION	M	Statements, questions, commands, etc. relating to the time-limited, medical purpose of the flight	"We will ERO the organ through the cargo door." (AC-medic) "If you have any requirements or requests you can relay them to me through the loadmaster once we are enroute. Is there anything special you want us to take care of right now?"
AIR PICTURE (GEOGRAPHY)	G	Any communication (statement, question, command, etc.) relating to the aircraft's physical place in space, including airways	"Plan on 24 left to Toronto." "From Trenton to Toronto the VOR is 36 miles."
SYSTEMS	S	Any communication relating to any of the mechanical, electrical, or navigational systems on board the aircraft. That is, any utterance that refers to the adjusting of a system will be classified as system-related, even if that system is geographical in nature (see example).	"For departure brief right seat let's start with Trenton on the TACAN and we'll check the localizers and switch them over to Campbellford before we start rolling." "Just tell me when you want the DME on Campbellford."
WEATHER	W	Any communication relating to weather, e.g., wind direction, gusts, icing conditions.	The winds are going to keep coming from the north. Must be a front moving through."
PROCEDURES and CHECKLISTS	CHLST	Any communication referring to checklists actioned or to be actioned, specific procedures, also any communications referring to clearances	"OK, whenever you are ready, you should probably do a checklist here." "OK when you are ready right seat we'll ask them for start clearance."

Table continues

Mental Model Coding Categories (cont'd.)

FUNCTION OR PURPOSE OF COMMUNICATION	CODE	DEFINITION	EXAMPLES
AWARENESS	AW	Simple declarative statements concerning the present states, and immediately impending* changes in the states of systems, the mission, air picture, weather, checklists. These statements serve to maintain and update the changing mental model and short-term goals. *as distinguished from preplanning	"Levelling 6,000 in the turn." "OK 8 miles back from Campbellford in the TACAN." "We've got a hydraulic low pressure light on #2." "OK, I'm going to push the power up." "Gear is up."
CROSS-CHECKING	CC	Explicit, overt noting of deviations with respect to another crewmember's actions, planning, calculations etc.	"You're off the glide slope." "Watch your airspeed." "You probably want to keep your airspeed down." "You're kind of diverging off the west from the VOR ..." "OK, if you want to fight her back down to 4 and show me up, that would be good."
IMPLICATIONS	IMP	Explicit and overt recognition of the consequences or ramifications of present system, mission, weather, checklists, and geographical states and the interactive effects of these states upon each other.	"Just considering your worst case scenario, would you be interested in lowering your gear and flaps into position now, just in case the other pump goes?" "The only thing I've got doubts about is the antiskid system because it is part of the touchdown relay." " ... other systems lost, we have no utility so we want to make sure that the brakes go to emergency."
PREPLANNING	PP	Explicit statements of future intentions or plans regarding systems, the mission, air picture, checklists & procedures	"Okay, so we are 15 miles back from Simcoe and if we do a teardrop so that we're back on the 047 ... from there we do a procedure to get us into 24R." "350 a good trot to Campbellford till we're airborne and we'll pick it up and hold it. 257 out of Campbellford to TO." "Depending on RWY conditions, I'd go to emergency or deactivate your antiskid just to be safe and basically be gentle on your brakes."

Table continues

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Mental Model Coding Categories (cont'd.)

ADDITIONAL CODING CATEGORY:	CODE	DEFINITION	EXAMPLES
SYSTEM KNOWLEDGE	SK	<u>Spontaneous</u> & explicit statements by crewmembers regarding how relevant systems operate, indicating their knowledge of systems as distinguished from reading information in flight manuals (e.g., the Z-10).	[re: gear override] CO: "they're not coming up" AC: "Hit the override switch there."
TASK PRIORITIZATION	TSKPR	Overt & explicit direction or request for direction concerning the timing of tasks in relation to one another	"Let's get the approach check done and then we'll deal with that ..." "I'll finish the post-takeoff check and then we'll deal with the landing gear problem before we get too far from Trenton."
CREW MONITORING	CM	Overt & explicit statements directed toward assessing and addressing crewmembers' workload, information load, or vigilance	"Just let me know how you are doing over there." "How are you doing there CO?" "Everybody got the ATIS?"
OPEN-LOOP COMMUNICATION	OLC	Lack of response of any kind to directions, suggestions, queries; also interruptions that *interfere* with building a mental model, information transfer, or the development of a team, <u>as distinguished from alerting interruptions</u> (e.g., FE must break in to alert the AC to a system emergency), or interruptions that involve one crew member picking up on and finishing another's thoughts and statements (which is evidence of a shared mental model).	

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Appendix B: International Symposium on Aviation Psychology (1997): Workshop Notes

The following notes were taken during the contractor's attendance at the Ninth Annual Symposium on Aviation Psychology, held April 27-May 1, 1997, in Columbus, Ohio (USA). For further information on these workshops and sessions, the reader is referred to the symposium's published "Proceedings of the 9th International Symposium on Aviation Psychology," R.S. Jensen & L.A. Rakovan (Eds.), Columbus, OH: The Aviation Psychology Laboratory, Ohio State University.

<u>Workshop 14</u>: Facilitating the Integration of Human Factors Education into the Operational Flying Curriculum, Mark Wiggins and Irene Henley, Department of Aviation Studies, University of Western Sydney, Macarthur. (Materials are titled: "Integrating Human Factors into a Flight Training Syllabus").

- Asserts that human factors training should start on the first day and continue on everyday; full integration
- Don't necessarily have to use HF jargon to make effective
- Signs and cues of HF phenomenon (concrete examples, cases studies) should be imparted, along with appropriate countermeasures
- Teach to recognise HF challenges and deal with them
- Emphasis was placed on the importance of the trainer's role in imparting understanding of human factors
- CBT is emphasised as a valuable learning tool: However, it is asserted that effective training, especially of human factors issues, still needs person-interaction as a necessary, even essential, element
- Training the trainers becomes especially important when the trainers serves as models for professionally appropriate attitudes and motivations
- Teach and model explicit self-evaluation and meta-cognitive skills so as to promote life-long learning
- Workshop materials included in final contact submission

<u>Workshop 5</u>: The Aircrew Behavioural Compass: A Descriptive Model for Categorising and Understanding the Personal Behavioural Styles of Pilots, Marvin Karlins, University of South Florida, Singapore Airlines.

- Primarily a personality approach to flightdeck behaviour
- e.g., halo effect of the nice guy/good atmosphere pilot; 1st officer doesn't want to destroy positive atmosphere; or, e.g.2 presence of management person leads to non-challenging

- why right seats don't challenge left
- goal to increase interpersonal effectiveness (though this left undefined and unmeasured, presumably)
- Karlins believes personal styles can be trained in or out via good instruction/mentoring and proceduralising the personality out
- Good instruction includes many video recreations
- All briefs therefore very important, especially tone of them
- Constant practise key to building this into the fabric of regular ops
- Once fleet behavioural styles identified, report incidences and set policy to change behaviour
- My assessment: too much emphasis on the personality aspect; workshop itself a little Mickey Mouse, facile
- However, suggests we should apply epistemic analysis (processes of freezing and unfreezing) to the total crew to get the truest picture of the total epistemic environment

Workshop 2: Understanding and Preventing Crew Error, Dr. Patrick Veillette, Aviation Safely Consultants.

- As this Workshop was booked at the time of registration, I pursued the author and arranged to have course/workshop notes sent later. Note that the numbering is not always consecutive and may reflect an edited version
- My impression is that this is a comprehensive laundry list of human factors implicated in instances of unsafe cockpit behaviour
- Also provided are recommendations for what to teach in a CRM course, though the list is similar to what is currently provided in many existing courses.

Note: Workshop materials for all three workshops are included with the final contract submission

Appendix C: ATG Aircrew Coordination Training (ACT) Notes

The following notes were taken during the contractor's attendance at the CF Air Command Aircrew Coordination Training (ACT) Session conducted March 10-March 11, 1997, by Air Transport Group trainer Maj. Frank Pelltier, 8 Wing, CFB Trenton.

These notes do not concentrate on the content of what was delivered in the course, so much as the nature of the andragogy employed. Suggestions and opportunities for improvement are noted, but reflect the author's own approach to training. Ordering of notes follows, approximately, the order in which topics are treated in the course.

Does ACT Work?
- Presentation of "data" on the efficacy of ACT
- CAE-Link Corporation workbook used many places, with reports of increased error protection in the months following the course of 8-10%
- Organisational evaluations attribute from 28% to 81% reduction in accident rates to this course or other ACT courses
- Clearly, hard to make the attribution directly to the course in the absence of formal evaluations studies (with, for example, wait list controls); evaluation confounded with a host of other factors
- The key hypothesis is still that changing attitudes works, that it spreads, that organisational culture then supports this, and that improvements are attributable to the training of new attitudes (all testable hypotheses, but none tested so far)

ACT Instructional Delivery: Main Methods
- Course materials used such as icebreakers, videos, exercises; still mostly chalk and talk from instructor — need more and better aids/materials
- Course book positioned as a generic building block to be revisited again and again and then customised, but few concrete recommendations are given as to how to do this; tough to teach common denominators in such limited time given heterogeneity of backgrounds of attendees
- Content delivered via MS Power Point
- Method of delivery often war stories: share experience (confidential, no risk, supportive environment promoted, but is it even close to being achieved?)

ACT Course Atmosphere: Intention vs. Reality
- Goal to create a no-risk, involving environment
- Get the sense people are still not really comfortable with discussing this openly after a couple of days (perhaps inhibition from presence of large contingent from DCIEM)

Course Goals
- Overall goal of course: impart changed knowledge, attitudes, skills; while first two may be achievable to some (evaluable, but unevaluated) degree, tough to do the last

CC-130 Context for Course
- Review of CC-130 accidents
- Past mission analysis rife with operation of hindsight bias (my opinion)
- Attribution of half of causes of crashes to ACT (48% to lack of aircrew co-ordination; 22% loss of Situational Awareness; 19% violation of regulations; 11% poor decision making)
- Also cite FedEx CRM course training and evaluation where 3% got "worse" (by what measurement criteria?); harps a bit (missionary-like?) on "good attitude"

HF and CRM: What it is?
- Listing of CRM phenomenon done by: describing it, defining it, giving examples, trying to define when it is most likely to occur, how to avoid (e.g., SLOJ, Strength of an Idea, Copilot Syndrome, Halo Effects, Excessive Professional Courtesy, Hazardous Attitudes, Hidden Agendas, etc.); divides into 2 rough classes: cognitive/mindset and social interaction
- Assessment of this strategy: elements are there but not enough meaningful integration to allow long term assimilation and integration of learning

Countermeasures
- Tools for combating these phenomena: aircrew co-ordination cycle, SOPs, AESOP Model, Two-Challenge Rule, Most Conservative Response Rule, Assertive Statements, Shock Statements, "Am I Safe" Checklist, etc.
- Teach meta-awareness about when such tools are used and should be appropriately used; combine with Awareness-Implications-Planning (AIP) Model (Hendy).
- Teach more specific skills for these; e.g., "Am I Safe" lists what to check, but not how to check them, what criteria to judge against, all the concrete aspects

Accident Review
- Accident case studies presented to build base of knowledge via post-hoc causal analysis (little evidence such exercises may transfer)

Policy and Regulations
- Section's goal is to describe their role, why they have come about, analyse the causes of deviations from P&R, list inadvertent and purposeful departures from
- Assessment: still a lot of laundry list teaching
- Something interesting in terms of teaching could be done with purposeful departures in the sub-class called 'necessary departures': should plan and get feedback from crew on proposed options, make a clearly communicated conscious decision (to build the mental model that is

shared), plan carefully (limit setting, contingency pre-planning), directly brief (corroborating mental model allows others to contribute timely information, expertise). Suggest they do a case study, then a role-play of how to do this well.

<u>Personality Styles</u>
- AC Personality Types: interesting but perhaps better taught as a situational than personality set of constructs/phenomena: state vs. trait issue

<u>Leadership</u>
- Next, sections on Power Bases, Leadership, Creating an Assertive Statement, Destructive Patterns, Constructive/Corrective Patterns
- Again, verbal review only, almost totally conceptual with few concrete examples
- On Leadership: task priority by people skills interaction conceptualisation; say *what* to do (namely, build confidence, trust, and support and gauge the reserves and capabilities of crew members) but not *how* to do it
- Creating an Assertive Statement: say how to do it (steps: opening, state concern, state problem, offer solution, gain acceptance) but despite how easy it would be to provide behaviour-based training for this, NONE is done
- Note: by this point in the day we are behind schedule and it is hot in the room; topics are skimmed over in the most cursory way and nobody is taking notes or being responsive any longer (instructor has lost them for the day)
- People skills like: giving expression to positive and negative feedback is trainable, but is left untrained, just talked about generally and in a cursory way — no detail, no concrete examples or case studies; refer to voluminous literature on feedback and how to give it in organisational behaviour texts

<u>Aircraft Commander's Responsibilities</u>
- AC's Responsibilities: very important topic from point of view of cross-training roles and responsibilities; other airmen must understand constraints/expectations that ACs work under in order to provide good followership; shared mental model must have these as primary component
- Late in day and we're behind so again, this most important topic skimmed over
- Again, the 'what' is imparted, but not 'how' on topics like: establishing clear authority and leadership, adjusting use of authority to situations, creating an atmosphere where crew participation can flourish, pre-briefing cockpit responsibilities, and quick resolution of disruptions

<u>Aircrew's Responsibilities</u>
- Respect/support AC authority, assertiveness with respect, when in doubt speak out, giving best information/judgement to AC in a timely way, etc.
- Again, these are the very micro-behavioural elements, paralinguistics, body language, etc. that can be practised and trained successfully

Aircrew Communications
- Again, much of this material is new and useful for airmen, but is glossed over due to the pace; unlikely to be remembered because it is not experienced nor practised; low assimilation to schemas so long-term integration and retention in doubt
- The most behavioural of the elements covered so far, so most amenable to training
- Needs to have much better case study materials and time for practice practice practice
- Example given about use of verbal information to describe an ambiguous stimulus; to what effect? (Point of the example was lost on me)
- Senders and receiver responsibilities: too much lecturing

Workload and Performance Under Workload
- Reviewed are: Causes and effects of high and low workload, how to recognise (cues), manage
- Inadequate treatment

Available Resources
- Review of internal and external resources
- Demonstration of using other members as resources: fun but of questionable teaching/training value
- Conclusions something like: Identify resources, discuss and decide how to use them, use the AESOP model; elements are there but need more clarity and cohesion

Situational Awareness
- Again, review of concept, symptoms, how to recognise, countermeasures to avoid losing, technique for regaining
- Return to idea of knowledge, attitudes and skills as training preparation and first defence, but with little time or ability to train skills

Overall Assessment
- Either: 1. Concretise the training and give much more time to skill development (which may entail a longer course), or 2. Concentrate on strong conceptual knowledge of human factors, decision making and aviation psychology in general, to provide sound schematic base for later OTJ learning of ACT skills (apportion skills to OJT).
- Either tack involves the needed development of behaviour-based teaching methods for skill development of CRM and communications skills
- Little content/development of fundamental left seat requirements like decision making under normal and anomalous flight conditions and cockpit resource management skills and requirements
- This is the first and best opportunity to build a community-wide, shared and institutionalised mental model of safe flight operations as practised by a multi-place interacting crew members

Appendix D: ITRC Symposium Materials and Notes

The following notes were taken during the contractor's attendance at the Information Technology Research Centre (ITRC) Conference entitled, "Online Learning 1997: Effective and Available". ITRC is located at the Davis Centre, the University of Waterloo (Tel: (519) 888-4540). Associates of ITRC who helped organise and fund the meeting included the Educational Network of Ontario, watAGE Inc., and SMART Technologies. The conference was held December 16th and 17th, 1996, and the contractor filled in for Dr. Thompson on the conference's second day, as she was unable to attend. This conference examined current methods for on-line learning, including:

- Creating and maintaining materials;
- Communicating among instructors and the learning audience;
- Distributing, assessing, and using data;
- Usability testing and analysis; and
- Integrating online learning into education, government, business and agency operations.

The reasons for the contractor's presence at this conference were four-fold:

- To learn more about electronic support for conventional learning methods;
- To learn more about the development and support of multimedia, online learning via the Web
- To learn more about Smart Board technologies and other recent advances in technology designed for instructional delivery
- To evaluate the viability of a web-based training solution for the CC-130 Hercules community.

The conference outline is attached. On day 2, key addresses germane to the contractor's goals were given by:

- Kevin Hooper, Smart Technologies (smarttech.com) and Toni DiPetta, Educational Network of Ontario, on "Smart Communications: Visual Human Interchanges in Real Time";
- Paul Beam, watAGE Inc., "The Online Learner: Developing Audience Expectations";
- Mark Chignell, Faculty of Engineering, University of Toronto, "Make It Work For Me: The Efficiency of Adapting Systems to Users"; and
- Robert Moore, InContext Corp. (www.incontext.com), "Information Organised for Human Exchange". (Substitute speaker for absentee presenter; not in conference agenda nor on attendance list)

Notes:

Hooper and DiPetta:

- Distance based learning linking up to 64 points via LAN, WAN, Internet, etc.
- Remote clients need software
- HTML databases; graphics-based: create objects and link them (e.g., test, graphics, sound, clipart, ppt, HTML, etc.)
- Enables CUCME, video-conferences
- Graphic links to homepage
- Smartboards allow collaborative notes to be taken, displayed to all users, saved to file
- Creates an audit trail
- My assessment: Smart Technologies provides powerful group-at-a-distance learning tool to facilitate communication and instruction

Beam:

- On-line instruction/training requires necessary triad of structured data (content), administrative systems, communications tools
- Key is in instantiating self-directed learning principles
- Provide progress feedback to learners in several ways: email, webchat, newsgroups, comments from evaluators, useraccounts, projects, instructor's comments
- Learners should, in parallel, evaluate the method of delivery using several methods (as above) to iterate delivery efficiency
- Create safe environment/coach learners to: query re: their problems
- Classify these problems
- Record audit trail for students of various abilities
- My assessment: classification of problems gives strong clues as to the development of mental models and where they are under-developed
- Analysis of systematic differences between C and A students in the audit trail should allow the development of metacognition models amenable for use by the C students: they should be able to learn-question-check and engage in other learning processes more like those students who are more successfully apprehending the knowledge when they are shown these more successful strategies, and then model them, incorporate them and practice them.

Chignell:

- Needs-based approach
- Give away the pedagogy/andragogy — make transparent
- Make Learners into teachers/authors
- Teach by having learners publish (case studies, projects, etc.); builds on the old adage that to really understand something you have to be able to teach it
- Give them all the tools needed to be researchers/authors

- This may often mean the tools should be general purpose rather than specific, but they should be adaptable
- My Assessment: Have incident and accident databanks in the Hercules community, and unrecorded personal incidents (or bogus ones), written into case studies for instructional delivery (via smartboard or other method) by the pilots themselves as part of their training requirement. Their analysis of the cases and events should be detailed and extensive, it should be evaluable, and should incorporate feedback as received by instructors initially and as received by users as the case is used and critiqued
- This strategy helps with the problem of insufficient case content and builds the critical mass of cases for course delivery quickly without relying solely on already over-burdened trainers; also captures organisational knowledge of senior pilots; allows them to articulate/display their superior systems and flight deck management knowledge; their cases serve as fodder for evaluation of many aspects of safe flight performance.

Moore:

- (Works with military)
- new definition of "document" as "Information Organised for Human Exchange"
- electronic, distributed, compound (multiple contributors)
- a frame or filter for objects/methods that act on the data
- documents are not just data, but become active processes
- re-use of knowledge important; subdivide learning components into small chunks for re-use again and again
- documents provide components
- the way the components are linked (e.g., HTML) are important
- take components from context to context
- SGML authoring (supports all HTML)
- SGML database-schema + data dictionary + data
- SGML as object-schema language — new and evolving
- Document = object frame; programming = authoring
- from HUI to GUI to DUI (Document User Interface)
- my assessment: have loose categories to start with, mark up only the text they use (echo technique), record users' choices as important data; build the mental model

Appendix E: Human Factors of CC-130 Operations: Volume 4, Training Systems Knowledge

The following report was written as the main substantive deliverable of the systems knowledge acquisition portion of the contract. It was included as Volume 4 of Hendy et al. (1998), and is reprinted here with page numbering as a stand-alone document.

Its official citation is:

Jamieson, D. W. (1998). Human factors of CC-130 operations. Volume 4: Training systems knowledge (DCIEM Report 98-R-17). Toronto, ON: Defence and Civil Institute of Environmental Medicine.

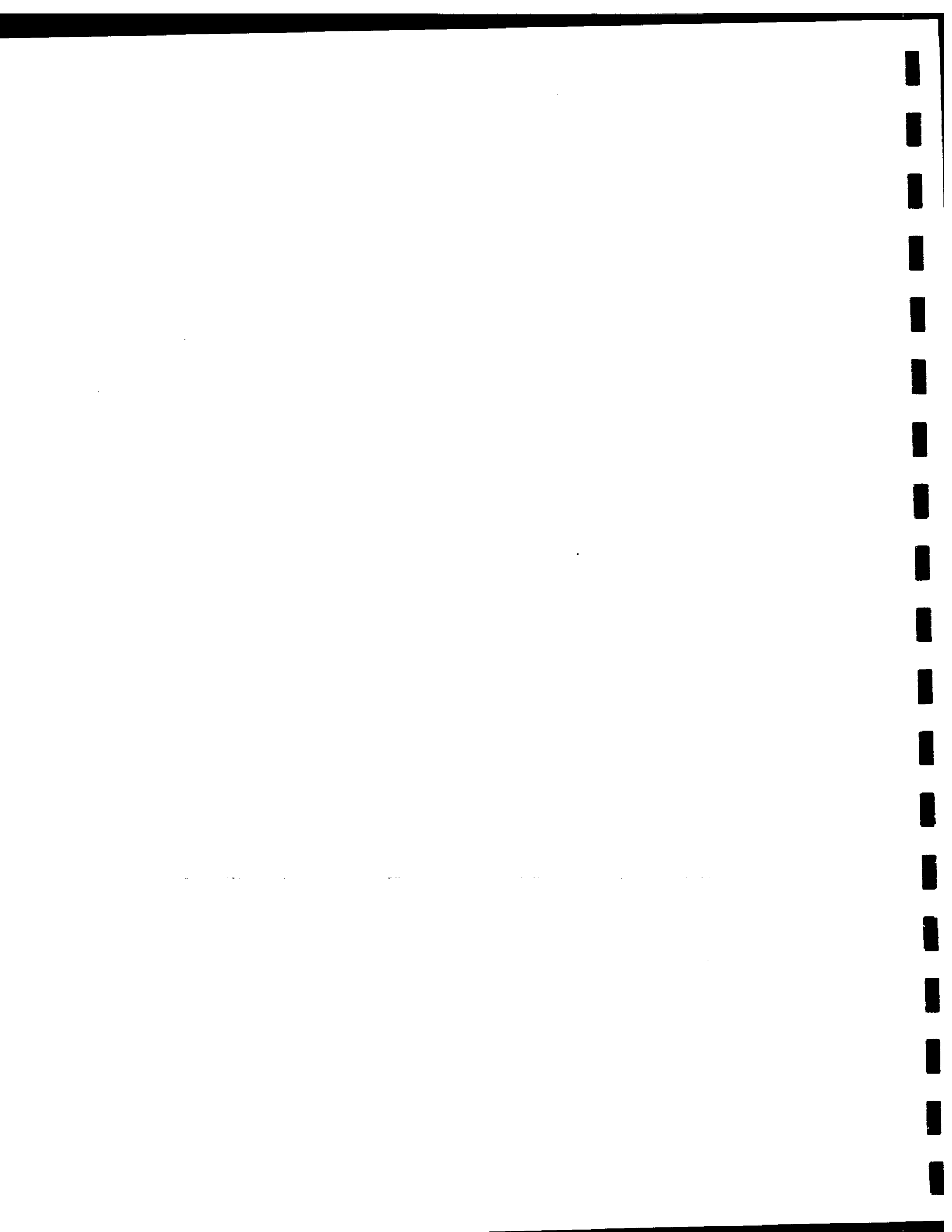# HUMAN FACTORS OF CC-130 OPERATIONS

VOLUME 4: TRAINING SYSTEMS KNOWLEDGE

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DEPARTMENT OF NATIONAL DEFENCE – CANADA

EXECUTIVE SUMMARY

The following recommendation, made in the June 1996 briefing to the Commander, Air Transport Group (ATG), served as the impetus to the work.

- Raise the overall level of systems knowledge among ATG aircrew by developing teaching aids and courses to accelerate the acquisition of knowledge and to compensate for lowered fleet experience levels through advances in training program delivery.

In this Volume, systems knowledge training is first placed within a general risk management scheme as an overall causal framework for securing safer and more effective operations within the CC-130 community of 1 Canadian Air Division (1 CAD). Systems knowledge acquisition is seen to be a latent risk factor, operating both as a precondition/psychological precursor of risk at the level of the individual, and as a systemic line management deficiency at the level of the organisation. Formal evaluation of the state of systems knowledge fleet-wide is needed to provide feedback to the organisation in its attempts to manage latent risks.

Current systems knowledge training practices within the organisation are reviewed next, including past assessments of the need for modernisation of training. It is concluded that while current training practices are sound, thorough, and professional in execution, there remains room for improvement because downsizing and experience loss have impeded the ability of 8 Wing, Trenton, to achieve training modernisation .

A selected review of best training concepts and practices is presented, based on the recent literature on education and training. Those concepts best suited to the CC-130 training environment are identified. The key areas covered include:

- the importance of life-long learning;
- a just-in-time knowledge-to-skill training model;
- problem-based (i.e., case-based), self-directed learning;
- effective use of interactive multi-media for training at the Operational Training Unit (OTU), for on-the-job training (OJT) and self-study;
- methods for the development of superior mental models of aircraft systems and their operational interdependencies; and
- the need for evaluation at three levels: trainee self-evaluation, OTU/OJT formal student evaluation, and organisation-wide monitoring and evaluation.

A set of recommendations is then presented, for value-added training system improvements in the area of aircraft systems knowledge acquisition. These recommendations are based on the best adaptable training practices that can be delivered within current organisational restraints, including:

- distributing more formal, detailed skill training to the Squadrons, while keeping conceptual mental model building the focus of the OTU;
- teaching the Awareness Implications and Planning (AIP) model as a conceptual approach at an early stage and throughout training so that it becomes habitual;
- using more case-based teaching, supported by video simulations of good as well as poor systems handling, making sure that aircraft system interdependencies, and the need for implicational thinking and pre-planning to deal with these, are illustrated;
- forging partnerships in the world-wide CC-130 community to build a library of cases quickly;
- leveraging the Smart Board software pieces — deploy the Smart Boards at both the OTU and OJT within the context of both problem-based learning and self-study, combining them with a case-based method, and intelligent tutoring for self-directed, continuous performance improvement — build the tutor to provide feedback that will develop pilots' abilities for objective, independent self-evaluation of the state of their systems' knowledge (i.e., meta-knowledge) and motivate self-initiated learning;
- develop appropriate standards and evaluation tools for this type of training;
- conduct formal evaluation studies to document the efficacy of these value-added improvements; and
- create a non-jeopardy database to monitor and track fleet-wide the development of superior systems knowledge.

The Volume concludes with a summary of the deliverables, the implications for implementation that are discussed throughout, and the resource requirements implied by adoption of these recommendations.

CONTENTS

INTRODUCTION

This is Volume 4 of a six volume series describing the outcome of a human factors study into CC-130 operations (see References [1-5] for details of the remaining documents in this series). In this Volume the issue of needed improvements to the training of systems knowledge is addressed. After reviewing the reasons why this was identified as an area needing improvement, such training is placed within an overall risk management framework for securing safer and more effective operations within the CC-130 community. Current systems knowledge training practices within the organisation are then reviewed, including past assessments of the need for modernisation of training. Following this, a selection of best training and education concepts is reported, based on the recent literature on education and training, showing which of these concepts are best suited to the CC-130 training environment. This leads naturally to a set of recommendations for value-added training system improvements in the area of aircraft systems knowledge acquisition. It is argued that there is a need to quantify, with suitable empirical documentation, the magnitude of these training improvements after deployment, and to monitor, fleet-wide, the evolving norms regarding pilots' systems knowledge. This would provide feedback to the organisation in its attempts to manage latent risks. Implications for implementation of these ideas for both the Operational Training Unit (OTU) and for On-The-Job Training (OJT) are drawn out and reported as to complete the analysis. Finally, the resource requirements implied by such changes are enumerated.

The following recommendation made in the June 1996 briefing to the Commander, Air Transport Group (ATG), served as the impetus to the work.

- Raise the overall level of systems knowledge among ATG aircrew by developing teaching aids and courses to accelerate the acquisition of knowledge and to compensate for lowered fleet experience levels through advances in training program delivery.

This recommendation resulted from the observation of inadequate in-depth aircraft systems knowledge demonstrated by several pilots in the Crew Behaviour Assessment Group (CBAG) behavioural measurement validation study [6]. These pilots had difficulty recognising, diagnosing, or ameliorating some of the aircraft systems failures incorporated into this event-based scenario. While a few limited observations do not make a fleet-wide trend, these observations were embraced by ATG as perhaps typical of a more general problem — at least on an intuitive and anecdotal level since adequate measures of systems knowledge proficiency do not currently exist that would document fleet-wide trends in this type of expertise.

1

2

SYSTEMS KNOWLEDGE IN THE MANAGEMENT OF RISK

Within Reason's [7] systems approach to risk management, adopted as a framework for the activities of the CC-130 study team (see Volume 1 of this series for a more detailed discussion), the acquisition of aircraft systems knowledge can be seen as occurring relatively early in the chain of organisation-wide activities in which 1 Canadian Air Division (1 CAD) engages. A lack of adequate and appropriate knowledge of aircraft systems can therefore be conceptualised most generally as a latent, as opposed to an active, failure in the accident sequence. Such lack of knowledge can be classed as occurring within two of the risk management system states earlier defined, namely 'Preconditions' and 'Line Management Deficiencies'. These two states correspond to control loops 3 and 4, respectively, of Volume 1, Figure 4 (repeated below, as Figure 1, for convenience).
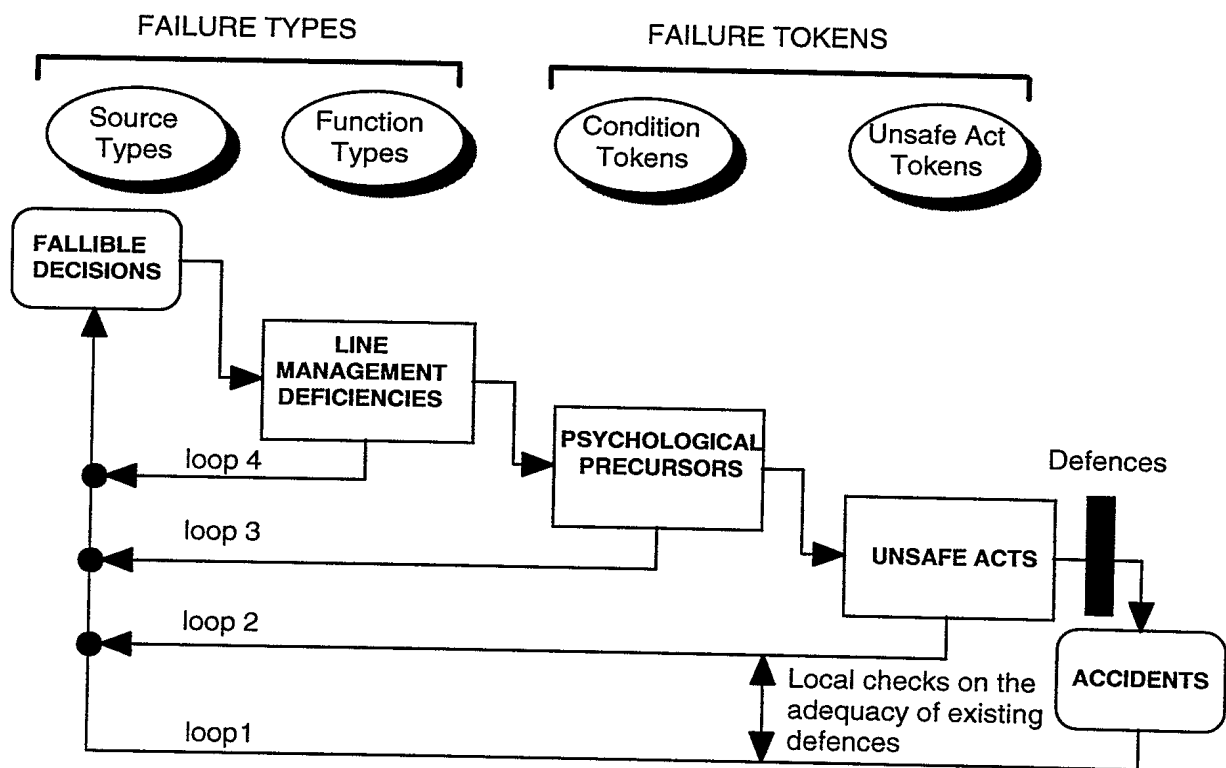
Figure 1. *Feedback loops and indicators for the management of system safety* (after Ref. [7], Figure 7.9).

As a Precondition/Psychological Precursor of Risk

Inadequate systems knowledge, possibly caused through a variety of factors such as experience loss, or an erosion of training or standards, sets a precondition for failure because key cockpit decision makers (Aircraft Commanders or ACs) are inadequately skilled to meet, with sufficient alacrity, common aircraft systems challenges, outages and failures. Unsafe acts become more probable in a context of lowered or inadequate systems knowledge, and the more unsafe acts attributable to this source, the more likely this latent failure may eventuate in accidents when 1 CAD's defences-in-depth are repeatedly tested due to this cause.

It is obvious to aircrew (anecdotal evidence; see also the study of dimensions of captaincy in Volume 5 of this report) that a key dimension of leadership and captaincy in terms of both safety and production, is a high degree of systems knowledge proficiency. No matter how it is initially imparted, or later developed, embellished, and translated into skill, systems knowledge is a necessary pre-condition for the prevention of unsafe acts, and for the recovery from them as well. In the terms used previously [6, 8], pilots must have a well-articulated and organised mental model of each aircraft system and of each system's interactions with other systems.

These mental models are complex cognitive representations of the various systems' functions. Such cognitive representations allow heightened abilities for:
- perception and situational awareness;
- judgement;
- implicational/inferential thinking;
- pre-planning; and
- dynamic decision making.

Each of these functions of aircraft systems mental models allows for faster and more accurate assessment and action, buying valuable time in the Information Processing (IP) model[1] trade-off between the time required to do what must be done and that time available to do it [9]. In addition, superior knowledge representation of systems implications allows for preplanning and decision making that can 'buy time' when necessary, again insuring that the IP Model ratio does not exceed one. Under such conditions of superior aircraft systems proficiency, advanced systems knowledge representations become skill-like in their implementation. This is a simple description of the preparedness that comes with high skill levels; well-developed mental models about aircraft systems contribute to more effective and efficient information processing about those systems, as well as to a reduction in workload stress and an improvement in both safe and efficient flight performance in real-time operations. Simply put, this state of mental model functioning can be taken as a definition of expertise with aircraft systems.

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[1] The IP model was one of the theoretical positions that guided this study (see this report, Volumes 1 and 5). The IP model claims that performance, error production and perceptions of workload are all driven by the time pressure (i.e., the ratio of time required to time available).

AS A LINE MANAGEMENT DEFICIENCY RISK

The development of superior systems knowledge that will ensure both safe and efficient flight performance can be, and is, imparted at many levels, and at many time points in the overall training of CC-130 pilots. One obvious place for intervention, as well as for monitoring systems knowledge to provide feedback to the risk control system, is at 426 Squadron — the OTU. In the context of lowered fleet-wide experience levels (see Volume 1 of this report), more effective and efficient delivery of systems knowledge training can serve to compensate, at least in some measure, for a loss of expertise. It was a goal of the CC-130 study team to identify those teaching philosophies, approaches, methods, materials, delivery systems etc., that can best add value to an already redoubtable training effort at 426. In leveraging even further the many solid approaches to training as well as training technologies currently in place at the OTU, it is hoped to be able to recommend improvements to training delivery that will push trainees more quickly up the learning curve toward high proficiency. It is also hoped to be able to document the efficacy of these improvements with suitable empirical evidence regarding their effects, in the form of formal evaluation studies. In addition to demonstrating the efficacy of the proposed improvements, these studies will serve as a model for the kind of evaluation studies needed by the organisation to track the state of systems knowledge , as pilots exit the various OTU courses.

In recognising the limited exposure that pilots have to 426 Squadron, components of training outside the OTU, that are in need of amplification or introduction, are also foreseen. In particular, OJT at Squadron is also a focus of the study team's recommendations. The distribution of superior training techniques to all levels and kinds of training exposure is the best way, it is considered, to achieve a fleet-wide improvement in systems knowledge. As in the case of the flight school, adequate evaluation, standards, and monitoring must be put in place for OJT that will allow multiple-source feedback on the normative state of system knowledge performance fleet-wide. This feedback will inform the risk management system at a deep level (corresponding to control loop 4 in Figure 1) of potential, or latent, failure in the area of knowledge of aircraft systems. Such a monitoring system is particularly important and timely given the near-term upgrade to the semi-glass cockpit for the CC-130, because past research has shown that systems interdependencies in such aircraft exacerbate the difficulty of training [10].

REVIEW OF CURRENT TRAINING

In Phase I of the CC-130 study, anecdotal evidence of inadequate aircraft systems knowledge among some crew participants from the crew performance validation study was observed, noted and reported to ATG [6]. In Phase II, activities were directed toward identifying and recommending mechanisms for the accelerated acquisition of systems knowledge both within formal and on-the-job training. Because it was Aircraft Commanders (ACs) who exhibited the clearest instances of lack of systems knowledge in the CBAG study (though it is recognised that it is likely only a very small minority of ACs that is not currently meeting appropriate standards), that focus was on the acquisition of systems knowledge among ACs at various levels of training. The current Phase II activities were therefore directed toward:

- conducting a review of current 426 training system methods, materials, and practices;
- conducting a selected review of the education and training literature — both theory and current practices; and
- making recommendations for value-added improvements to the training system in terms of effectiveness, efficiency, and evaluation.

REVIEW OF 426 SQUADRON TRAINING

The review of 426 Squadron training philosophy and regimes included interviews with trainers and course developers, reviews of written course materials and limited attendance at some courses. The focus was on conversion training and the upgrade course, since it was pilots' (particularly ACs') system knowledge more than systems knowledge at any other crew position that most directly affected the outcomes of the flights we observed in the validation study.

This review confirmed that some excellent training resources exist at the Squadron currently for the acquisition of systems knowledge, and that a starting infrastructure exists to expand upon these already-excellent offerings. It is considered that current 426 Squadron training is well-grounded in education/training theory, is both comprehensive and thorough in coverage, and is professional in execution. Future efforts at adding value to this system should use these existing elements as a base for what would be characterised as a small to moderate re-engineering of current instruction. However, there are areas that can be leveraged further, some that would be classed in the area of training effectiveness, and some in the area of training efficiency.

Particular strengths observed in the training of systems knowledge include:
- clear, lesson-specific instructional goals;
- comprehensive course materials;
- effective examples and scenarios;

- use of a multi-tiered approach (i.e., lectures, mock-ups, part-task simulations, full-motion simulations, etc.);
- effective use of cases;
- presence of experts in the classroom to address problems/questions; and
- use of smart board technology as the mechanism of instructional delivery in certain instances (i.e., fuel, and hydraulics at present).

Areas of potential improvement at 426 Squadron, and for OJT, that were identified include:
- striking a new relative balance between the conceptual content and the detail communicated about systems;
- use of OJT/Squadron Standards Officers to continue the conversion of knowledge to skill in a way consistent with and co-ordinated by trainers;
- an operations-specific training needs assessment conducted at the various Squadrons to tailor some training toward customers differing in role requirements;
- updating materials and examples;
- use of even more facilitation-type teaching with case study examples;
- explicit methods for developing superior mental models of aircraft systems that include awareness, implicational thinking, planning, and decision making regarding those systems;
- explicit methods for developing mental models of aircraft system interactions;
- opportunities for training, developing and exhibiting systems knowledge and systems knowledge-relevant decision making in dynamic, more realistic, event-based scenarios (low-to high-fidelity);
- completion of the outstanding smart boards for systems not yet represented and taught in this mode;
- increased functionality of the smart boards (e.g., to allow and stimulate implicational thinking about systems);
- improved, formal evaluation and organisational feedback at every stage of training; and
- provision of tools and motivation for career-long self-study, student feedback and the development of self-evaluation skills.

The review of systems knowledge training was done in conjunction with a review of current education and training practices. The latter served as a filter through which to view current CC-130 training practices. Before turning to this review, it is instructive to compare the CC-130 study group's independent assessment of systems knowledge training circa 1997, with one conducted by ATG in 1990. In some respects the review and recommendations made some 7 years ago strongly foreshadow the position taken in this Volume.

HYPHER'S STUDY OF CC-130 PILOT TRAINING MODERNISATION

In 1983, Mr. Peter Hypher, then Operational Research Advisor, reviewed the CC-130 training systems at the Operational Training Unit as part of the Commander ATG's initiative to modernise the pilot and aircrew training systems [11]. He updated his review in 1990, under contract to the Operational Research and Analysis Establishment [12]. Both reviews distinguished between the concepts of cognitive and psycho-motor skills acquisition, emphasised

the need for a progressive learning approach, and sought to encourage the adoption of progressive training aids.

Hypher's main arguments were:
- that learning of cognitive and psychomotor skills within ATG took place largely in isolation and needed to be integrated/alternated all along the continuum from the OTU Conversion, to OJT, to Upgrade; and
- that the ideal training system would incorporate training aids ranging along a continuum from textbooks and lectures, to computer-based training (CBT) lessons, to part-task trainers (PTT), to cockpit procedures trainers (CPT), to the full motion simulator (Sim), and finally to the aircraft.

By 1990, he saw CBT as desirable and feasible and spent much of his report reviewing and recommending it as the best method for transmitting basic knowledge and training.

Since 1990, several aids have been added to the training system, including the cockpit mock-up (CMU) arising out of the CC-130 Avionics Update Programme (AUP), and the Smart Board systems packages (fuel and hydraulics delivered, with remaining systems on order: electrics, propellers, etc.), that go a long way toward meeting the recommendations Hypher made. Importantly, many of Hypher's observations with regard to the needs of the training system hold as true today as they did 7 years ago. Organisational stresses in the form of downsizing and fleet-wide pilot experience loss have prevented 426 Squadron's ability to modernise its training as rapidly as hoped.

When Hypher's arguments are applied to the issue of systems knowledge acquisition, many of the assertions and recommendations are accepted, but issue is taken with several points too. Without exhaustively reviewing his main contentions (which stand in his own companion document), the areas of basic agreement with his training system vision, and areas where there are differences, are summarised below.

It is agreed with Hypher [12]:
- that the present OTU systems knowledge treatment "...over-teaches the technical detail..." (p.17);
- that there needs to be more emphasis on "...good airmanship and airspace awareness initially than on technical detail..." (p. 22) at the OTU;
- that the OTU tends to teach "...ten years of systems failures..." (p. 3) in a few days at the Conversion course and that this overloads the student;
- that there is a need for a progressive learning approach in the area of systems knowledge acquisition (p. 3);
- that there is a need for progressive training aids to teach systems knowledge (p. 19);
- that the present training system consists (still) of too much chalk-and-talk with regard to systems knowledge (p. 7; though this is changing with the introduction of each new Smart Board module); and
- that a rating system be introduced to assess the training value for each aircraft system of each operational training flight (p. 77).

His call for the introduction of self-paced study is also accepted, though there are differences on the best mechanism for this. Hypher recommended traditional CBT, which was state of the art at the time, and this represents the main area of apparent discrepancy between the recommendations of the CC-130 study team and those of Mr. Hypher. While it is true that traditional CBT has many advantages over lectures, including shortening systems knowledge acquisition times and bolstering knowledge retention, the developmental efforts and costs attached, estimated as taking anywhere between 250 to 800 person hours of preparation per hour of CBT instruction, and as costing between $15,000 to $30,000 per hour of final CBT product, are prohibitive. Moreover, these sorts of estimates are for classical CBT, which amounts in many cases to expensive page-turning software of largely text-based material. To fully realise the advantages of sound, video, animation, and simulations within a classical CBT environment would add incrementally to these costs.

ATG has not in the past chosen the classical CBT option for training systems knowledge, and in hindsight the study team concurs. CBT is not the appropriate alternative even at this time, especially in light of the development of another (but relatively less) cost-intensive vehicle for instruction — the Smart Board CDs. These can powerfully substitute for CBT — indeed, they are a form of it — while at the same time, it is believed, achieve considerable training efficacy (it is argued below that this training efficacy should be documented empirically via formal evaluation research using objective performance measures, evidence that will quantify the Smart Boards' effectiveness and increase their marketability in other C-130 communities).

Recent advances in authoring systems for multi-media training suggest that using commercially available authoring software may now be viable for the creation, maintenance and revision of multi-media courseware for the CC-130. This flexibility in design and the ability to amend lesson plans has been, heretofore, largely lacking among CBT packages. These can now be usefully and easily employed as courseware generators among multi-media literate trainers. It is recommended that caseware and courseware be built, placing as their centrepieces, the Smart Board system simulator module. Emphasis on preplanning and decision making will be manifested as lesson objectives that surround, and are placed 'on top' of the basic Smart Board capability. Were Mr. Hypher to have been writing today, given his stated recommendation to integrate sound, video, and simulation within classical CBT, it is suspected that he would in agreement as to the training potential inherent in the Smart Board systems.

Another key area of disagreement in the learning model adapted for the current review of CC-130 training, as compared with Hypher's own recommendations, is his statement that conversion training should emphasise "...'how to operate systems' rather than 'how they operate'..." (p. 129). It is believed that a sound conceptual basis — understanding how and why the system operates as it does — provides a key knowledge structure within which technical detail and skill can be incorporated and retained. Enough *how to* operational knowledge must be imparted to allow aircrew to contribute as useful team members upon exiting the conversion course, but a sound conceptual understanding is a necessary pre-condition for differentiated, integrated, and retrievable systems knowledge. This is especially the case as the issue (increasing in importance with the Avionics Update Project [AUP]) of interconnected systems functioning [13] is

broached. Situational awareness, implicational thinking, pre-planning ability, and decision making are all facilitated by a sound mental representation of systems' causal interactions.

One of Hypher's stated reasons for suggesting CBT, was to secure self-study opportunities and access for students. Digital compression and other computer technology advances since the time of his writing now make network-hosted, fully interactive multi-media CBT with simulation components realisable in the near term as a tool for systems knowledge training. The Smart Boards represent software pieces that can be fairly easily adapted to be self-paced, self-directed distance learning applications, concurring with and delivering Hypher's earlier vision for career-long currency maintenance and performance improvement.

REVIEW OF EDUCATION AND TRAINING LITERATURE

Several of the areas for improvement, identified above, were inspired as a result of a selected review of the current literature on education and training. Those trends, themes and principles judged most pertinent to CC-130 pilot training are summarised below as six main points. At each point the principle involved is reviewed, what is believed to be its best application within the CC-130 training environment is described, and the implications that adoption or further extension of the training approach/principle would have are outlined. Recommendations are summarised only after describing all the points in order to avoid redundancy, because many of the themes are strongly inter-related. Resources that may prove useful in future implementation are referenced, and listed in the resource appendix attached (Appendix 1).

There are six key themes involved in this review. These range from motivational factors that will ensure more effective training and an emphasis on conceptual models, all the way to specific ideas concerning appropriate self-paced multi-media tools that will simultaneously improve training efficiency, effectiveness, and evaluation. The six themes to be described are.

1.   The Importance of Life-Long Learning.
2.   A Just-in-Time Knowledge-to-Skill Training Model.
3.   Problem-Based (i.e., Case-Based), Self-Directed Learning.
4.   Effective Use of Interactive Multi-Media for OTU/OJT and Self-Study.
5.   Methods for the Development of Superior Mental Models of Aircraft Systems and their Operational Interdependencies.
6.   The Need for Evaluation at Three Levels: Trainee Self-Evaluation, OTU/OJT Formal Student Evaluation, and Organisation-Wide Monitoring and Evaluation.

The Importance of Life-Long Learning

Life-long learning is a concept, of great currency value of late, in educational theory and practice [14, 15]. Educators and trainers have long recognised that the pace of technological invention and change means that the half-life of most knowledge is limited. In an age of rapid advancement, it becomes requisite that practitioners in every field keep constantly in tune with the latest trends and developments in their areas of expertise. Responsibility for the pursuit of

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continuous education and performance improvement throughout the career- and life-span now vests with individuals as well as the training arms of organisations. Life-long learning is the way of the future for everyone, and its need is already here.

The concept of life-long learning is viewed as being essentially a motivational one. Eventually, through the development of assessment instruments that will allow the organisation to carefully identify, screen, and select those candidate pilots in possession of both a natural propensity toward self-improvement via self-motivated study and a natural heightened recognition of the need to stay current, 1 CAD will be able to select individuals who come bearing the right, 'life-long learning', stuff. However, such diagnostic measures of personal motivation and selection are not yet in existence, and so steps that are systemic and situational in nature must be put in place that will motivate aircrew toward self-improvement at the same time as giving them the kind of tools and affording them the kind of learning environment where motivated self-study can flourish early on — and be maintained throughout the career-span. In other words, 1 CAD must create, even more than it has already largely successfully done, the means, motive and opportunity for life-long learning.

There are larger issues of organisational structure, career paths, incentive systems, organisational commitment and the like that will need to be broached to ensure the success of instilling a philosophy of life-long learning [16]. This Volume will focus on tools for self-directed, continuous improvement rather than on these larger organisational issues. It is believed that the kind of balanced training model proposed (see next section) will make training more enjoyable, (even) more respected, and more motivating than it is currently, in keeping with the kind of role (and status) within the organisation that the training system must occupy.

Implications. Occupational environments that promote life-long learning must support such learning with proper tools and aiding. Limited teaching budgets suggest that continual improvement and education is done most cost-effectively if the student assumes major responsibility for their upgrading via self-study. In the area of systems knowledge acquisition, this suggests that appropriately gauged self-study packages be available to pilots on an on-going basis. This also implies that experts be available for consultation in support of self-study, and that software, for example, be available to provide an appropriate degree of 'help' when needed in the absence of such experts. Help can range from the provision of indexes and glossaries during self-study all the way to intelligent tutoring systems (see below). Since most of these self-study materials are likely to be computer-based (i.e., software), this also implies some investment in pilots' computer literacy early on in their training to maximise their self-study and life-long learning potentials.

A Just-in-Time Knowledge-to-Skill Training Model

Effective training starts with the conveyance of knowledge, by which it is meant that a conceptual understanding of the subject based on theory and examples is laid down, and through practice this knowledge becomes appropriately skill-based. Simple principles of knowledge acquisition suggest that a strong conceptual grounding, or infrastructure, is necessary in the knowledge acquisition process. Later detailed understandings are best learned and retained when

they can be assimilated to an existing conceptual 'scaffolding' (i.e., assimilation of knowledge is always easier than accommodation).

In the present instance, this conceptual scaffolding can be understood in terms of solid, cognitive schemata, or mental models, of aircraft system functioning. These mental models promote higher order cognitive processing, such as inference, reasoning, trouble-shooting, etc., because they represent not just what a system does, but how and why. Once a strong conceptual mental model is in place, the assimilation of details in practice is an efficient process. It is considered that some training benefits may accrue if the limited exposures pilots have to 426 Squadron is even more concentrated than at present on improving this conceptual understanding (i.e., laying the basis for superior cognitive representations), while OJT continues to concentrate on the assimilation of details and the development of skill. Over-teaching of detail at the OTU is not a wise use of limited ground school time.

The latter point relates to the important issue of the timing of learning. Learning is maximised when concepts are acquired 'just-in-time', that is, when they are actually needed in practice; knowledge that is transmitted but is unrehearsed quickly atrophies (as anyone who has taken a course but not applied it for several months will attest). 'Just-in-time' is a term that strongly implies skill transmission at the squadron operational level. Therefore, careful consideration must be given to articulating when it is that different kinds of knowledge are optimally acquired within the entire training system. An over-emphasis on detail to the detriment of conceptual understanding at 426, when this is more appropriately transmitted at Squadron, will not produce long-term retention.

It is important to note that for a conceptual scaffolding to work, it must be supported by tools that allow strong conceptual understanding to be stimulated at OTU and strong knowledge-to-skill conversion to occur during OJT. The Smart Boards provide just such a ready training tool/aid for the development of stronger conceptual understanding in the form of the schematic visual representation of aircraft systems presented (usually) in the upper half of their screen displays. The ability of the student to manipulate this schematic interactively, and to receive feedback about the results of their control actions, promotes a strong conceptual understanding of how and why the system operates as it does. In addition, the simulation capabilities of the Smart Boards, in combination with appropriate cases that teach operational skill in the relevant contexts, and at the pertinent times, allow the tool to achieve the aim of knowledge-to-skill conversion as well.

Implications. The division of training labour suggested by this re-balanced training model implies an increased reliance on skill development at the Squadrons, which, in turn, entails a somewhat higher level of support for training at the Squadron level than currently exists. This support should come in the form of transmission of the Smart Board learning tools to all squadrons, accompanied by training of squadron Standards Officers in their facilitator role within the scheme of problem-based (case-based), self-directed learning (see next section). Central co-ordination, monitoring, and evaluation of the entire training model, when delivered in this way, is required, and should be based most appropriately at the training Squadron.

Problem-Based Self-Directed Learning

One influential mechanism for fostering a stance on education that can be described as 'life-long', at the same time that it imparts strong concept building, is the use of problem or case-based, self-directed learning [15, 17-19]. Because there are many ways to implement what is deemed to be a 'problem-based' and 'self-directed' approach in education, care should be taken in defining these terms. When this is done it will be discovered that not all elements of the approach lend themselves to easy adoption in the military training environment. However, carefully pruned, the techniques of this approach can be usefully applied both to the OTU and to OJT at the operational squadron levels. This approach is summarised, and an attempt is made to show how it can be usefully adapted at the OTU and for OJT.

Problem-Based Learning. Classically, problem-based learning as been described as involving the presentation to students of specific real or simulated case studies in a particular field that present a problem or challenge requiring solution. It is contended that via such 'situated learning' new material is better understood and retained, because it is learned in concert with environmental cues to be encountered in the real situations in which the learning will be relevant [20].

The cases are meant to provide a springboard for learning, and, importantly, for learning about learning. Typically directive forms of instruction such as the chalk-and-talk lecture are not used with this approach and the instructor's role is re-defined as being one of an intellectual shepherd, mentor or facilitator. Students work both individually and in small groups, to define actively the issues and questions to be addressed, the tasks to be done, and the information to be discovered or recruited. In this way the method is self-directed in addition to being problem-based. After discovering on an individual basis the information to be used, trainees then work together with the information they have accumulated to synthesise, discuss, and integrate it, and to make final recommendations about the problem solution.

Because problems are multi-determined and multi-faceted, the information sought usually must be extracted from a variety of disciplines and sources, and in a variety of ways. It is contended that this is a learning challenge and intellectual environment that is more representative of the real-world problems and performances expected of employees in almost every field once they graduate from training. And it is also asserted that such 'contextual learning' (i.e., learning as needed, just-in-time, and in the context where it will later be applied) makes the learning more enjoyable and more effective as well.

The group-based learning portion is integral to the process, as it is a central 'method of work', a method again often representative of the real world group working environments in which trainees will spend most of their professional lives [21, 22]. Thus, the knowledge gained about group dynamics in the group-centred part of this inquiry/learning process also transfers to the real work environment, where people are expected more often to perform in groups than alone (especially in highly technical work environments).

Co-operation and teamwork skills are fostered from initial training onward when group-based learning is integrated into the method of instruction, as people become aware of such things as:

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- how to manage differential ability;
- how to contribute both to teamwork and taskwork;
- how to participate in others' learning;
- how to read one's own and others' emotional reactions;
- how to build trust;
- how to manage and resolve conflict constructively;
- how to give feedback to one another usefully and sensitively;
- how to manage difficult people; and
- how to instil as the key motive of team life the performance needs of getting the job done safely and effectively, rather than letting fear and competition drive human relations and team performance in either the training or real world environment.

Self-directed, problem-based learning is usually a new mode of learning for new inductees and as such, care is taken at the outset to provide training to trainees in the method of training itself, so that students understand the approach and their responsibilities within it. During this initial training trainees are engaged in learning how to learn.

Trainers also often need to be trained in the mode of facilitation required, which is usually quite different from their accustomed roles as 'experts professing'. They must learn in explicit terms how to help students learn how to learn. Trainers are asked to set cases, encourage and guide trainees without forcing or directing, provide a role model of critical thinking and critical self-examination, and assist group members in self-evaluation.

Trainers are also responsible for the evaluation of each member of the group and for shepherding group processes where necessary. Evaluations can be formal and on-going — conducted at the end of each session — or can be performed more infrequently at mid- and end-of-course. And of course, objective performance standards still serve as essential benchmarks of knowledge proficiency against which hard performance evaluations can be measured.

Everything in this approach is directed toward making the student responsible for their own learning and to set patterns and habits of learning suitable to their needs. This method of operation should be employed continuously throughout their professional career. However, it is important to note that while self-directed, learning is neither self-willed nor self-indulgent in this regime. Clear expectations for training, training standards and performance objectives are set and met. While the system of learning delivery is intended to be flexibly adapted to individuals' learning styles, what is not open for negotiation is the requirement to produce training outcomes of effective and efficient subject matter knowledge and proficiency. Therefore, the approach is self-directed and student-centred from the point of view of the training delivery mechanism, but the programme itself is not self-directed. Considerable guidance and modelling of best-learning practices is one of the key elements that trainers must provide in their re-defined role, and the course content is theirs to set as they see fit. This, in summary, is the 'how' of problem-based learning as it is currently conceived and practised.

Overview of Domains of Knowledge in Problem-Based Learning. The 'what', or content, resulting from this approach is usually divided into three intended domains of impact.

1. A knowledge base is grown: Knowledge consists of both facts and concepts. The problem-based learning approach tends to emphasise the development of sound conceptual understanding and models within which to organise facts (i.e., conceptual scaffolding), as well as the knowledge of how to gain access to specific information as required. This places it in keeping with the training model proposed for the OTU, wherein a greater emphasis on conceptual understanding is recommended than is currently practised.

2. The second domain of learning is skill: In this case this will include not only systems operational skill, procedural skill, and psychomotor skill, but also:
   - critical appraisal skill, such as system situation awareness, the application of judgement, a questioning attitude, the ability to solicit and weigh evidence (like the quality of current flight data), system diagnostic and trouble-shooting skill, etc.; and
   - learning skills, such as the ability to self-identify deficiencies in one's own systems knowledge, the ability to correct deficiencies, knowledge of resources available to correct knowledge deficits, and understanding the importance of constantly renewing one's base of knowledge (i.e., motivated remediation).

3. Finally, problem-based self-directed learning behaviours: This is a third kind of domain knowledge — namely the acquisition, development and maintenance of personal qualities and attitudes appropriate to the profession's roles and tasks. This knowledge includes:
   - team leadership and followership skills;
   - mentoring skills modelled from the examples provided by the intellectual shepherds — the trainers; and
   - a motivated attitude of life-long learning — continual self-improvement.

Thus, in total, the process is intrinsically oriented toward the kind of personal and teamwork development required of left-seaters in their professional conduct inside the cockpit and outside of it as well.

The Case for Case-Based Training. The self-directed learning philosophy need not be problem-based. It is important to review from a cognitive and methodological perspective, why case-based (nee: problem-based) teaching methods are likely to be effective in meeting the goal of fostering *expertise* in an accelerated time frame within the CC-130 training program. Here is why knowledge is better transformed into operational skill using cases.

Formal conversion training is often designed such that operators receive a level of training necessary to produce 'competent' performance, that is, a performance level sufficient to produce safe system operation [23]. At the end of formal conversion training, pilots can probably be best described as 'trained novices' [24] rather than as anything approaching experts. At this point their acquired knowledge is unlikely to be well-differentiated or well-integrated, characteristics classically associated with expertise. On a continuum that ranges from compartmentalised knowledge to integrated knowledge, the structure of the systems mental models held by trainees at this point in their training is likely to be classed towards the fractionated, or compartmentalised, end of the continuum. The training challenge presented by systems

knowledge acquisition is, of course, to devise tools and methods of training delivery that will allow trainees to progress along this continuum of integration toward the more expert end — in the absence of real world experiences with all likely or unlikely systems situations.

With reference to specific kinds of knowledge to be trained, pilots will have three sorts of understandings represented in their developing mental models of aircraft systems at this point in their post-conversion course:

- declarative knowledge,
- procedural knowledge, and
- operational skill [25].

Declarative knowledge is the factual knowledge possessed about the system, things like its components, controls, and functions. Procedural knowledge refers to the rule-based knowledge possessed, such as how to operate the system and how to perform sub-component tasks. Operational skill is the ability to integrate the first two forms of knowledge, the declarative and the procedural, in a goal-directed, multi-task, time- and resource-constrained environment, in other words, in the kind of dynamic decision making environment that the CC-130 flightdeck represents. It also includes executive function sorts of knowledge, such as recognising when activities are required (situational awareness, implicational thinking, prioritisation, etc.) and knowing how to co-ordinate these activities to meet the demands of real-time operations (e.g., pre-planning, managing time, allocating aircraft and team/human resources, etc.).

Expertise is most related to the last of these three knowledge contents — the operational application of knowledge in real time. Studies have demonstrated that operators matched on their declarative and procedural knowledge (as assessed by test scores), but differing in expertise, show marked differences in their operational performance effectiveness [26]. Trained novices typically exit from formal training with incomplete declarative knowledge and incomplete and only loosely integrated procedural knowledge, yielding a 'buggy' cognitive representation of each system [27].

Usually, expertise is obtained over time — through the accumulation of real world experiences that are integrated into the basic mental conceptual model. By experiencing a wide range of situations, acting to control systems within those situations, and receiving feedback about the results of control actions attempted, pilots' declarative and procedural knowledge becomes integrated into operational skill. Unfortunately, OJT sometimes does not expose all pilots to all pertinent situations, so that line flying accumulated over a period of time does not always build expertise sufficiently. In addition, after-action or after-event reviews may be missed [28], insufficiently detailed, or informal at the Squadron level, causing valuable training lessons to be foregone and learning opportunities to be lost.

Herein lies the great potential of a case-based self-directed training system for use primarily at OJT. By collecting and articulating in the form of case-based learning, a widely representative sample of typical actions and Standard Operating Procedures (SOPs), as well as known incidents, accidents, anomalies, and typical faults, one can with simulation and a repertoire of cases, approximate the breadth and depth of training that would normally occur over a more extended

period of time. Encapsulating the organisation's knowledge in this way also serves to preserve its organisational memory of 'war stories' and 'hangar flying' —its informally archived cases.

Note that training success will depend in large measure upon the selection of appropriate training scenarios under a case-based approach. 'Appropriate' entails a choice of case scenarios that provides the proper environmental contexts and cues that reflect the way systems knowledge is actually used in that system's domain. If chosen or built wisely, the simulator cases will promote the integration of knowledge and enhance operational skill [29]. By trading cases with other fleets operating the C-130 airframe, an even fuller repertoire of situations can be represented.

Problem-Based Learning's Best (and Appropriate) Practices for OTU/OJT. It is recognised that 426 Squadron OTU currently employs a variant of a problem-based learning component in its use of case studies. A radical re-design of the training system, in favour of a completely problem-based approach, is not suggested. Chalk-and-talk lectures and other forms of teaching should continue to have their proper place in the methods of training or delivery used.

However, for the future, when such training challenges as the Avionics Update Programme arise, it is believed that the benefits of life-long learning and self-study via self-directed learning will become more necessary as mechanisms to help aircrew remain current in an increasingly systems knowledge-intense environment. While the role of the training instructor remains important and will not be diminished in this new scheme (in fact, it is enhanced and more appropriately deployed), students must be given better resources, skills, and the motivation for self-directed learning and self-paced study as an additional avenue toward continuous performance improvement. Further, they must be exposed to the kinds of group-based learning which mimic their work environments on the flight deck. Once the group-based format is acquired during ground school at 426, it will be easily recapitulated as a 'method of work' in the operational environments at the squadrons. Moreover, it has great potential as a distance-based group method using suitable real time communication across computer networks, allowing teams to be composed from members at a distance — such as from different squadrons.

Certain, limited aspects of the problem-based learning approach described above, can be translated into training practices that will have a positive payoff for the Hercules pilot community. In fact, existing elements of the OTU's current lessons, structures and philosophy lend them naturally to a problem-based approach. Class sizes, for example, are already small, much in keeping with the 5-6 member groups recommended by most problem-based programs. Lessons are already designed that focus on systems failures, a good springboard for the problem-based mode. And a compendium of 'war stories' (although as yet undocumented) can also act as excellent grist for the problem-solving mill.

The 'limited aspects' of the approach, referred to above as appropriate areas for adoption, are summarised in the following list:

- it is not recommended that the entire training effort be converted to this format — lectures are still the most efficient mode of rapid information transfer (except for CBT) when this is what is required, for example in early learning;

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- more study must be given as to which specific lessons are best delivered in the problem-based mode;
- implementation should be phased, and slow to moderate in speed;
- proper training in the method for trainees must be supplied — such training is essential in teaching requisite skills for problem-based learning and in setting expectations for training and self-efficacy — the latter factors have been shown to be instrumental in the effectiveness of training [16];
- proper training for trainers must be executed, enabling trainers to assume their new roles as facilitators, mentors, Subject Matter Expert (SME) models, resources for self-evaluation, etc.; and
- objective evaluations must be developed (subjective forms of evaluation, inappropriate to the military training context, are often used in applications of problem-based learning).

At present, the times, places, and choice of learning path used by the student are still largely in the hands of the training system. The results of problem-based learning approaches indicate that, within limits and with considerable guidance at times, trainees' learning is more effective when they have some control over these factors. Students learns best when they can identify their learning needs, select learning methods that suit them best, select the location (time and place) where learning is maximised, and learn to identify through appropriate unsolicited, and later requested, feedback, whether or not they are achieving their goals.

A suitable tool for self-paced study is needed that would allow such flexibility in the learning of systems knowledge and in the continual upgrading required to remain current on the complex systems contained in the CC-130 at present and in the future. The basics of such a self-study tool already exists in the form of the Smart Board system simulation interactive CD ROMs. While currently this tool is used primarily in the classroom at the OTU, it can be amended for use as a stand-alone self-directed learning resource made available at the Squadrons and for use at home. As its hardware requirements are currently within the abilities of most home PC systems on the market today (and in the future), and as the software upgrades to these packages needed to facilitate self-paced study do not require additional PC system capabilities, this tool has excellent self-directed learning potential.

To fully realise the learning potential of the Smart Board 'part task simulators', several ways in which this technology can be leveraged are suggested (see next sections), for example, by combining them with video re-creations of documented incidents/accidents and known problems, by adding an Awareness-Implications-Planning (AIP) overlay module to begin to explicitly teach AIP principles as habits of thought, and by adding some intelligent tutoring capabilities (see below).

Implications. To summarise, the addition of a problem-based learning focus in the OTU and beyond carries with it several implications:

- the requirement to train trainees in this method of work at OTU (initially at the conversion course or earlier for pipeliners), so that they may continue this form of education at OJT — this is critical to its success in the creation and effective management of work teams;

- the requirement to train the trainers in this method both at the OTU and at the operational units;
- the need to create self-paced study tools (via software extensions of Smart Board); and
- the need to create and manage a compendium of training cases.

Effective Use of Interactive Multi-Media for OTU/OJT and Self-Study

Recent trends in technical education point squarely to multi-media packages as a currently preferred major mechanism of course delivery. Efficacy studies show the reduced knowledge acquisition times and enhanced knowledge retention levels achievable via these packages, be they traditional computer based training (CBT) or low to mid-fidelity simulations [30, 31]. Another chief advantage of multi-media is its potential for self-study application outside the classroom.

Specific ways in which the Smart Boards may be leveraged to improve them even further are now reviewed. Following this, a recent development in intelligent tutoring is described — one that employs cases as method within a multi-media environment, in keeping with our emphasis on problem- or case-based teaching methods.

Improvements to the Smart Boards. Smart Board modules are excellent training aids, and early anecdotal evidence of their efficacy regarding learning speed and retention from 426 Squadron is extremely promising (personal correspondence). It is understood that their initial development was for the training of technicians, but it is believed that they can be even further enhanced to achieve the kind of pilot knowledge and skill acquisition objectives enumerated in this Volume. They should therefore be finished on a fast track for all systems not currently represented in this format, and appropriate applications should be developed for the conversion course, pilot upgrade to left seat course, and Flight Engineer's (FEs') course at the OTU, as well as for applications at the Squadron level. In the terms already discussed for effective, efficient, and evaluatable training, the Smart Boards lend themselves readily for application because:

- the schematics provide a visual conceptual scaffolding of the kind whose importance has been emphasised as the central learning objective for pilots at 426 Squadron;
- the Smart Board software is easy to distribute to Squadrons, hardware infrastructure notwithstanding — the full system dynamic representation in the 'lower' half of the display is an effective detail/skill developer that can be resourced repeatedly at the Squadron level to enhance the conceptual underpinning imparted at ground school and to integrate declarative and procedural knowledge into operational skill;
- with relatively simple enhancements, the AIP formulation can be integrated with current Smart Board representations (see next section) — the focus again will be on system implications and system interdependencies; and
- Smart Board feedback functionality can be incorporated anywhere along a continuum from non-intelligent interfaces (e.g., pop-up windows with verbal answers) to intelligent ones (e.g., intelligent tutors) — because an eventual goal is to allow self-directed learning, it is recommended that at least some measure of intelligence is put behind the tutoring system.

The potential for self-study using the Smart Board is obvious (see last point). Some direction will have to be given as to the appropriate (or standards-based) level at which the material is expected to be learned for a given crew position, but the potential for learning to whatever depth is desired by pilots should be preserved. The following improvements are recommended.

- Allow aircrew to interact with systems simulations: when illustrating cases, having a dynamic representation of aircraft systems in real time in the form of a Smart Board display, as well as a real-time video simulation of cockpit events (played on-screen eventually as hardware is upgraded, and via a parallel presentation medium initially), will be a powerful aid to training. The instructor should be able either to stipulate the end point of the dynamic system or to render ineffective certain student actions, so as to be able to simulate real aircraft cases of incidents and accidents where pilot control actions proved ineffective.

- Allow monitoring, evaluation and feedback of student actions: whether in-course or in self-study mode, the smart boards can be engineered to come equipped with 'canned' starting system parameters. By recording obvious indicators such as pilot control actions and their sequences, reaction times, and responses to open-ended queries (e.g., problem awareness and diagnosis, implications, pre-planning, knowledge of system interactions, etc.), instructors (or an intelligent tutor) can evaluate a student's systems knowledge. Such measures taken over time would allow tracking of student progress. Used as a formal evaluation method, normative data could be collected about fleet-wide trends using a non-jeopardy data base. Especially in self-study mode, feedback to the student can be given in a way that provides raw data for the development of meta-knowledge (knowledge about the state of one's knowledge), an important precursor of expertise and objective self-evaluation about proficiency in knowledge and habits of thought.

Intelligent Tutors for Simulation. It is encouraging to have recently found a training tool with many of the formal properties that have been reviewed above as being desirable best training practices. This tool was conceptualised independently of this review, but is convergent in its recommended methods for training delivery. It is reviewed now in some detail, noting at the outset a number of ways in which it is similar and number of ways in which it differs from the current proposals for renewed training delivery.

Chappell and Mitchell [27] recently described an architecture for a computer-based training system for operators of complex dynamic systems, the Case-Based Intelligent Tutoring System (CB-ITS). This can serve as a conceptual roadmap for leveraging the investments made to date by 8 Wing in the Smart Board systems knowledge delivery modules. It is similar to the approach recommended in this Volume, as follows:
- it is intended to help pilots enhance and maintain expertise;
- it is inherently case- or problem-based, providing users with normal as well as unusual operating situations;
- it emphasises the acquisition of sound conceptual underpinnings for systems knowledge — the 'how' and 'why' of systems functioning, not just the 'what';
- it includes a simulator that allows students to practice translating their procedural knowledge into operational skill;

- it includes an intelligent tutor with variable ability to provide intelligence and instructional control as a function of student needs; and
- it is inherently closed-loop and systems-based (e.g., in its use of feedback to the student to help null the error signals while learning).

Chappell and Mitchell's approach is different to the approach to instructional delivery recommended in this Volume, in the following ways:

- it is designed primarily as a self-directed form of OJT, whereas the approach recommended for the CC-130 would marry it to both OTU and OJT in terms of a common approach and method of work;
- it does not integrate an AIP framework (see next section);
- it does not integrate teamwork into the method of work;
- it has less emphasis on developing high level self monitoring skills and self-evaluation; and
- it uses a different simulation platform.

These points stated, the utility of intelligent tutoring systems (ITSs) lies in their ability to tailor instruction to the needs of individual students. To do so, such systems contain four components:
- a domain expert,
- a student model,
- the instructional method, and
- the tutor interface [32, 33].

The domain expert is a model representing knowledge that characterises expert performance, including declarative and procedural knowledge, and operational skill. The student model represents the tutor's changing knowledge of the student's knowledge. By comparing at any point the domain model with the student model, the tutor selects teaching strategies such as cases, illustrations, hints, coaching, etc., that will close this expert-student gap. Such contents are delivered via interaction with the student using the tutor interface.

An ITS is intrinsically closed loop or cybernetic in nature, in keeping with the overall theme we have struck regarding systems theory. In attempting to null the 'error signal' between student and expert, the ITS exerts control actions on the student. As a student becomes more advanced, the ITS exerts less control and models its expertise to a decreasing degree along a continuum ranging from active prompting, to providing feedback when it notes an error or anomaly, to minimal intervention (i.e., only providing updates on systems at checkpoints, when errors are no longer recoverable).

Collins [20] suggests that an ITS delivers a form of 'cognitive apprenticeship' to the student by demonstrating expert performance in the context of realistic task scenarios. In doing so it helps students to better integrate knowledge of systems and procedure into operational skill because the knowledge of systems required for safe and efficient flight performance that is illustrated occurs in a multi-task, real-time simulation. Cognitive apprenticeship has been used with some success in several training systems that teach performance and decision making in naturalistic decision making environments with complex systems [25, 34].

During simulation, CB-ITS allows students to make the implicit knowledge contained in its expert model explicit at any point in time. The student simply must ask why the steps in an activity may have been prescribed by the tutor to receive reasons that describe the pertinent declarative and procedural knowledge and integrate it into the situation in progress. This too promotes the development of operational skill and perhaps meta-awareness of the state of one's knowledge as well.

Other expert systems offer similar capabilities, and may even allow better development of students' expertise and meta-knowledge. For example, the expert system knowledge elicitation package EXSYS prompts students with questions about the state of their knowledge [35]. During this process students may at any point ask why the question itself is being asked by the system. A tutor that describes why it is making queries, in the manner and order in which it is, can usefully model the expert's thinking process. The ability to reason about novel situations is a hallmark of expertise, and among the most important things to model and learn along the road to expert knowledge is the sequence of appropriate questions to ask. The implicit causal model of systems operations held by the expert that allows reasoning, a model that one would like to have students learn, is often well exposed by observing the expert's process of inquiry, that is, the processes for generating new knowledge.

In summary, several expert knowledge representation software simulation packages exist that can be usefully built into the Smart Board system. When incorporated as intelligent tutors, these have the potential to provide effective and efficient training via self-study.

Implications. Implied in the use of multi-media packages is that 8 Wing should formally evaluate their efficacy (as has been begun for the Smart Board software). Chief downsides of multi-media include, of course, the initial development costs where customisation is needed. Corporations are placing such materials on their intranets for distance education purposes and self-study, implying additional costs for IT positions to support it, authoring software and instructor training, course management software, etc. The integration of an intelligent tutor will require an initial phase of expertise extraction and system representation in the domain expert model built for each aircraft system.

Development of Superior Mental Models of Aircraft Systems

Pilots in the CBAG validation study fell down on systems knowledge in two ways: first, because they had trouble in the initial recognition or diagnosis of problems and solutions, or second, because they failed to adequately take into account and plan ahead for possible implications of the systems problems they encountered. By teaching as a mental heuristic the Awareness-Implications-Planning approach — namely, how to be more aware of developing system states, how to create a habit of thought to consider the future implications of the systems problems experienced, and how to pre-plan for various systems and inter-systems contingencies — pilots will come to routinise in their thinking the very kind of diagnostic abilities they most need to solve systems problems.

The longer term view of this approach is to state that it is consistent with the emphasis placed elsewhere (this report, see Volume 5) on the theme of cockpit decision making, especially on the part of ACs. In this case, AIP contributes to decision making about systems in particular, and about the entire mission, as systems problems are considered in light of the big picture.

Implications. One way to instil an AIP mental approach to systems considerations is to query pilots in mid-simulation about what they are thinking about the systems they are operating. This would require the capability for the instructor to stop the simulation to make the inquiry (or allow the pilot to record their thinking in response to a pop-up window query). As this might prove disruptive, an alternate tack is to make the AIP inquiry part of all after-action and post-flight reviews (including part-task and simulator training), and consider making it overtly manifest via inclusion in training checklists, say during the take-off and approach briefs. At minimum, a simple extension of instructors' current case scenarios that would ask pilots about systems implications, both in the future and for other systems as new faults are encountered, would go far in making this higher order mental model checklist habitual.

Appropriate and valid objective assessment instruments and standards need to be developed that would make such implicational thinking and pre-planning activities subject to formal evaluation. Feedback will be needed to allow students to develop an awareness of their strengths and weaknesses in these higher order cognitive skills (especially in self-study mode), and the fleet can be monitored squadron-wide to index the development of such safety skills in the non-jeopardy database.

The Need for Evaluation at Three Levels

Consistent with the general approach and framework of control systems theory, students also need appropriate feedback in order to evaluate their progress and achieve learning (i.e., null the error signals they are receiving about whether their actions on the environment are perceived to move them toward their goals). Mechanisms for this are many. The need for evaluation to occur on at least three distinct levels has been identified, namely:

1. Trainee Self-Evaluation
2. OTU/OJT Formal Student Evaluation and Organisation-Wide Monitoring and Evaluation; and
3. Formal Efficacy Study

Trainee Self Evaluation. The development of meta-awareness is a main goal of self-evaluation. This refers to the developing ability of a student to think about their own learning — its completeness, strengths and weaknesses, habits of thought, barriers, etc. Only when a student is capable of diagnosing what they do not know, and is motivated to correct this deficiency, can they be said to be a self-directed learner. This kind of meta-awareness is a demonstrated correlate (and most likely, cause) of independent thinking and expertise. It must be explicitly modelled as a habit of thought by trainers instructed about its importance, and themselves taught how to articulate their tacit expertise.

OTU/OJT Student Evaluation and Organisation-Wide Monitoring. In preparation for documenting the efficacy of the suggested modifications to the training system in general (e.g., use of more problem-based teaching with cases) and the Smart Board modules in particular (use of cases, self-study, intelligent tutor, etc.), standards of training will need development and evaluations of student performance against those standards will have to be performed. Student evaluation in quantitative terms must be part of the revised training package, along with mechanisms for student feedback about performance. Tracking pilot performances in the area of systems knowledge

- to establish a baseline, and through time, at exit from the various pilot training courses at OTU, as well as
- via the creation of a no-jeopardy data base build on spot-testing at OJT or appropriately systems knowledge-intensive, event-based, full-motion simulator scenario tests delivered during continuance training,

will serve as mechanisms for individual and fleetwide evaluation, respectively, of systems knowledge proficiency.

Formal Efficacy Study. Finally, using the assessment instruments and standards developed for proficient systems knowledge for each system, a formal study of the efficacy of this training as compared to either:

1. a 'pre-improvement' baseline, or
2. another CC-130 training environment,

should be conducted. The first option is preferable empirically, and because the main mechanisms for the re-engineered course delivery are the case-based approach and the Smart Board technologies, these are the main avenues of potential improvement and therefore should be the main locus of evaluation. If their efficacy can be demonstrated, this will be powerful evidence for the teaching methods recommended. This training product can then be 'sold' to other CC-130 fleets world-wide and to the CF fleet-wide.

Implications. Again, if implemented at 8 Wing, self-evaluation training would require feedback to students and the attendant support for it, especially via 426 and Squadron training/standards experts as well as by appropriate software-based feedback. New standards will need to be developed for evaluation purposes (e.g., for AIP), and a fleet management system and no-jeopardy database to accumulate fleet wide information to track trends in systems knowledge community wide should be instituted. A formal efficacy study may require the co-operation of another C-130 fleet for comparative purposes.

RECOMMENDATIONS

In light of the best educational and training practices as enumerated in the six themes in the previous Section, and building on the considerable strengths of the current training system, the following recommendations for systems knowledge training improvements for Phase III of this project are made. These have been made in light of the constraints of staffing complements, fiscal restraint, organisational restructuring, and existing computer hardware and software infrastructures, and reflect, it is believed, realistic goals.

1. <u>Distribute more formal training to the Squadrons</u>. Strong conceptual foundations in aircraft systems should be an increased focus of training to compensate for experience loss, and are most appropriately conveyed during the limited exposures pilots get to 426 Squadron (rather than an over-emphasis on detail in that venue). Convey more of the detail at Squadron, where knowledge becomes skill, and do so more regularly and formally via scheduled training, evaluation, etc. The overall plan should be orchestrated by 426, in consultation with Squadrons after an assessment of their needs. An increased role for OJT may imply more training of Standards Officers in educational theory, use of case-based instruction, computer literacy, methods of evaluation, etc. However, the results of this process will be that Squadrons will have more of a voice in creating the kind of operations-specific training of systems knowledge they require on the line, and will 'own' the training to a greater degree.

2. <u>Use more case-based teaching</u>, supported by video simulations of good as well as poor systems handling. Case-based teaching is both efficacious and enjoyable. It can be further enhanced in two ways. First, it may be paired with video simulations of real aircraft incidents/accidents, as well as illustrations of best practices. The videos would be created using incident/accident/best practices transcripts as a basis and using role-playing reservists or retirees as actors. This would require use of the full-motion simulator for videotaping (using typically the E and F sessions of the training programme). Second, cases can be embedded within the Smart Board presentation and learning format with or without accompanying video simulations. One focus of the case-based systems knowledge teaching units would be to illustrate system interdependencies — and the need for implicational thinking and pre-planning to deal with these. Given the high costs associated with linking the dynamic systems portrayed in the Smart Board modules, this is the most effective and cost-efficient approach to teaching causal inter-linkage between aircraft systems. In order to overcome a main obstacle to case-based teaching, the lack of suitably developed cases, it is recommended that training partners in the world-wide CC-130 community be found that would agree to share their cases.

3. <u>Leverage the Smart Board software pieces</u>. Deploy the Smart Boards at both the OTU and OJT within the context of both problem-based learning and self-study. Combine them with a case-based method of instruction, and intelligent tutoring for self-directed, continuous performance improvement. Build the tutors to provide feedback and develop pilots' abilities for objective, independent self-evaluation of the state of their systems' knowledge.

4. <u>Teach the AIP model as a conceptual approach</u>, at an early stage and throughout training so that it becomes habitual.

5. <u>Conduct formal evaluation</u> studies to document the efficacy of these value-added improvements.

Recommendations for Implementation

Systems knowledge training will be multi-stage, involving both 426 and Squadron-based training and instruction. It should incorporate:
- formal training opportunities;
- strong conceptual mental model building;
- adequate practice opportunities for the development of skill (including dynamic decision making with respect to systems wherever possible in simulations, part-task trainers, etc.);
- case-based learning;
- exposure to experts;
- self-study training; and
- feedback, reinforcement, and evaluation for the student.

Details of the implementation should be worked out with 8 Wing and 426 Squadron. The following tasks will need to be considered to complete the full implementation:

- determining the needed staffing complement at 426;
- determining the staffing and support needed at Squadron;
- an organisational analysis of the co-ordination needed between 426 trainers and Standards Officers at Squadron;
- a training needs analysis that stipulates the skills demonstrable at proficiency for each aircraft system;
- a training needs analysis that views each system in the context of its operational environment, for tailored systems training at Squadron;
- an evaluation of how much detail needs to be imparted at 426 vice Squadrons;
- determining the needed level of computer literacy for students and trainers, and delivering this training;
- training the trainers/Squadron officers in recent advances in case-based teaching theory and their roles as facilitators;
- determining how to make self-study packages accessible to students (e.g., via extended 426 hours, inter/intra net access, etc.);
- completion of all deliverables (courseware, caseware, etc.); and
- a formal efficacy study of the training.

CONCLUSIONS

Despite downsizing, and corporate raiding of its pilots, 1 CAD, through its OTU and OJT, continues to deliver a quality training product in the area of systems knowledge acquisition, and continues to provide innovative approaches (e.g. Smart Board Systems) to training. However, when compared to other fleets, and reviewed in terms of the education and training literature, systems knowledge training is in need of modernisation in terms of both effectiveness and efficiency of training philosophy, materials, methods, and evaluation.

Modernisation of systems knowledge training is especially important in the current context of lowered experience levels, as a compensatory defence against latent failures that otherwise would be caused by insufficiently prepared pilots or inadequately rigorous training regimes within the line management system. Modernisation of systems knowledge training methods is also timely in light of:

- training advances made for training semi-glass and cockpit flightdecks;
- the impending conversion of the CC-130 fleet to the semi-glass cockpit; and
- the identification (both in the aviation community in general, and within the CF CC-130 community in particular) of training for systems knowledge complexity as a major challenge for aircraft so equipped.

Modernised systems knowledge training will need to be:
- multi-staged and progressive;
- distributed more to OJT for improved integrated skill development;
- problem-, or case-, based;
- retooled to add higher order cognitive functioning with regard to systems (e.g., systems situational awareness, implicational thinking regarding systems problems, and planning for system and inter-system contingencies);
- career-long via self-study opportunities, which include the development of self-evaluation skills based on meta-knowledge (i.e., appraising what you know, realistically knowing what you don't know, and identifying what you need to know);
- based on efficient training tools such as interactive multi-media simulations incorporating performance feedback; and
- evaluated in the formal terms of an efficacy study.

Fleet-wide efficacy of the training over time, as well as long-term trends in absolute levels of systems knowledge fleet-wide, should be monitored via a no-jeopardy database of systems knowledge evaluations collected from several sources:
- from systems knowledge performance evaluated on exit from the Conversion and left seat upgrade course;

- from systems knowledge performance in appropriately designed, event-based scenarios given during continuation training simulator sessions (i.e., scenarios that incorporate systems knowledge demands); and
- in terms of reported incidents and accidents involving poor systems knowledge.

Implementation of the systems knowledge training proposed in this Volume will require an investment in:
- the Smart Boards System as the corner-stone training tool;
- leveraging those CDs to even greater educational benefit (e.g., by adding the AIP — Awareness, Implications, and Pre-planning — heuristic, self-study, generation of a library of training/simulation cases, use of simulation in concert with video re-enactments, development of intelligent tutors for self-study, etc.);
- hardware and software infrastructure improvements at OJT;
- training both trainers (OTU and OJT) and trainees in the methods of case-based instruction;
- additional training personnel assigned to the OTU to oversee the improvements, modernisation, and direction of the OJT portion of the training; and
- general IT and computer training support.

Key benefits of the recommended systems knowledge training modernisation are:
- increased **safety**;
- increased operational efficiency; and
- a potentially saleable training package (i.e., philosophy, structure, tools, evaluation, etc.) to the C-130 community world-wide, and to the CF fleet-wide.

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ACKNOWLEDGEMENTS

APPENDIX 1: LISTING OF RESOURCES

RESOURCES

The following resources have been assembled from a variety of sources. Most are brief descriptions culled from the Proceeding of the Society for Applied Learning Technologies' (SALT) annual conference entitled, *Interactive Multimedia '96*, which was held from August 21 to 23, 1996 in Washington, DC and attended by the author. A copy of these proceedings is held at DCIEM.

LIFELONG LEARNING RESOURCES

Contact: The Canadian Alliance for Lifelong Learning (CALL)
Suite 400, 20 Bay Street,
Toronto, ON
M5J 2W1

Telephone: (416) 325-4211
Fax: (416) 325-4675

e-mail: CALL@gsro.carlton.ca
Web: http://gcll.carlton.ca

CALL is a non-profit organisation committed to developing an action plan for lifelong learning in Canada and around the globe. It is associated with similar organisations around the world through its membership in the World Initiative in Lifelong Learning, based in Brussels.

One of the major foci of this alliance is on practical issues involved in the implementation of learner-centred environments, methodologies, technologies, and social strategies. They keep a case-study catalogue of actual examples of workplace models of continuous learning, geared to the application of the newest technology or the newest learning models, such as learning organisations, self-directed learning, learning via the Internet, the electronic classroom, distance education, etc.

Because the lifelong learning philosophy and methods such as problem-based learning are now being applied down to the kindergarten level, they span all age ranges in education. However, there is a particular focus within this span on adult education in general (e.g., within human resources development on productivity improvement strategies based on continuous learning and career planning) and on workplace training in particular (e.g., creating and sustaining learning environments within government/industry environments; impact of new technologies; electronic classrooms, etc.).

SELF-DIRECTED LEARNING RESOURCES

Title: The McMaster Medical Education Philosophy

Contact: Health Science Centre
                Faculty of Health Sciences
                McMaster University
                1200 Main Street West
                Hamilton, ON
                L8N 3Z5

                Telephone: (905) 525-9140

Since its inception in 1969, McMaster University's Health Science Centre has pioneered radical innovations in medical education. With nearly 30 years experience in the student-centred, problem-based, self- and group-directed learning philosophy, it stands as an excellent Canadian resource for the introduction of effective new methods in the lifelong learning field. Widely copied both within medicine (e.g., Harvard Medical School) and without (all other McMaster faculties), it is a respected source of information. McMaster holds a week-long, biannual visitor's workshop which serves as a briefing programme to its methods.

CONFERENCE ON INTERACTIVE MULTIMEDIA '96

This conference was sponsored by the Society for Applied Learning Technologies (SALT). Section headings reflect particular themes. The following presentations are noteworthy.

Performance Support System Rescues

Title: Use of the Internet to Assist in Creating CBT, Performance Support And
                Interactive Learning Programs

Author: *John Kellum*, VP and GM of Multimedia Tools, Asymetrix Corp.

How to create quick, easy, cost-effective CBT, PSS, and interactive learning applications. Supplied internal education to Boeing.

Title: How to Design and Build User-Centred Integrated Training and Performance
                Support System

Authors: *Janis A. Morariu*, Peak Potential, Inc. and *Eric J. Malecki*, M Multimedia, Ltd.

Describes their Integrated Training and Performance Support (ITPS) Design Methodology, which includes 5 types of goals/requirements and proceeds through five stages. Case study

example is the FAA's Training and Evaluation Support System (TESS), developed according to the methodology, as the FAA's prototype model for determining training cost-benefits and Return on Investment (ROI).

Title: Performance Web[SM] Case Studies: How Training Organizations Are Using the World Wide Web

Author: *Michael Gallagher*, Director, Sales and Marketing, AERA, Inc.

Application of browsers to presentation of technical documentation and training via intranets. Case studies include NASA Goddard.

Special Design Resources

Title: Incorporating Cognitive Strategies and Metacognition into Interactive CBT

Author: *Anne-Marie Armstrong*, Instructional Designer, AERA

Provides a guide to designing screens that meet cognitive learning objectives, as well as evaluation of such objectives.

Title: Work Breakdown Structures (WBS): An Automated Systems Approach To Planning Technical Training

Author: *Darrell Tatro*, Program Coordinator, AEGIS Training Center, and *Marilyn, B. Newman*, Training Specialist, AEGIS Training Center

Aid to planning and implementing large-scale training programs; can be used as a methodology for planning overall training strategy, and multimedia training/tools within this strategy.

World Wide Web Training Resources

Title: Internet Access for Beginners (CD-ROM)

Authors: *Mary E. Sand*, Program Manager, Technical Training, FAA, and *Nicholas Chandler*, Director of Training Systems, New Media Division, SAIC

A CBI course that teaches and uses the skills needed to distribute and maintain text-based and other media-based teaching/learning products over the Internet (including CBI multi-media materials). The course teaches beginning Internet skills so as to avoid user frustration, time wastage, etc., while also serving as an introduction to CBT-based education and training.

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Title: Training on the World Wide Web: Alternatives in Design and Development

Authors: *Ann Barron*, Associate Professor, Instructional Technology, University of South Florida, *Brendan Tompkins*, Programmer, and *Kord Kutchines*, Programmer, Analysis and Technology, Inc.

Presents new authoring tools, programming languages for interactive courseware creation, including HTML, Java, Shockwave, IconAuthor and PERL. Design guidelines are enumerated as well.

Title: How to Create Your Own Internet-Based Training Course

Author: *Pardner Wynn*, President, Stanford Testing Systems, Inc.

Demonstration of how to create a complete Internet-Based Training (IBT) course using IBTauthor, an off-the-shelf authoring tool.

Title: US Department of Defense On-Line Internet Journal for Training and Performance

Authors: *Leslye O. Fuller*, Instructional Technologist, Defense Business Management University, *Bart Morrison*, Senior Analyst, Analysis and Technology, Inc., and *Thomas J. Edwards*, Combined Arms Support Command, US Army

On-Line journal mounted to leverage the shared experience of US forces' application of technology to education and training. Idea exchange via usegroups, topical forums, downloadable journal articles, demonstrations of new technology, etc. Topic areas include human factors, cognition, CBT, intelligent tutors, simulation, distance education, adult education, multimedia, training devices, etc.

Title: Internet Treasures for Trainers

Author: *Jodi Bollaert*, Instructional Technologist, Ford Motor Company

Listing of web sites, gophers, and newsgroups for training specialists.

Title: Air Force Distance Training

Author: *Thomas E. Wolfe*, Chief of Distance Learning Instructional Design Branch, Air Force Distance Learning Office

Covers the expansive growth of distance learning in the USAF with CBI, interactive courseware, and interactive multimedia. Exhaustive coverage suitable to an audience from beginners to practitioners, dealing with intranets to MBONE.

Multimedia Development Resources

Title: Storyboarding That Really Supports Multimedia Development

Authors: *Gary E. Davis*, Multimedia Development Specialist; Lucent Technologies, and *Robert C. Fratini*, Senior Advanced Media Consultant, AT&T Network Systems; Lucent Technologies

Lesson planning for case study presentation via multimedia can be done easily by storyboarding. This paper describes the organisational factors needed to support successful storyboarding, as well the Multimedia Information Modeler to be used by the SME in lesson planning for multimedia.

Title: The Power of Interactive Video for FAA Course Development and Delivery: Lessons Learned

Author: *Phyllis Peters Marson*, FAA

Paper on interactive video training in the FAA. Only marginally relevant, but included here should the interactive teleconferencing of course delivery ever be considered.

Title: Interactive Multimedia Learning Systems

Author: *Michael Dulworth*, Insync Corp.

A good primer of multimedia learning systems, including how learning theory applies, the development process, and authoring systems. Includes a brief description of the four levels of multimedia learning: from customised linear presentation, to instructor-led/non-linear presentation, to facilitator-led training, to self-paced training.

Title: Rapid Scripting -- A Non-Traditional Approach to Storyboard Development

Author: *Mary F. Bratton-Jeffery*, US Navy

Current trends in authoring packages. Rapid scripting was developed to go beyond paper and pencil development tools and produce synergistic effects among interactive courseware production team members.

Training and Development Resources

Title: The After Action Review Process: A Heuristic Computer Assisted Tool For Training

Author: *Robert C. Hughes*, Program Manager, Cubic Applications

After Action Review (AAR) is a computer-assisted process designed to provide feedback after computer-assisted training, and to evaluate decision-making, courses of actions selected, performance against objectives and team interactions. The process promotes metacognitive development and awareness of the epistemology of what people are actually doing, and is highly compatible with the systems approach to training and education we have proposed. A meiotic teaching approach, it is based on Bloom's taxonomy of educational objectives and the metaphor of "candling", that is, observing without disturbing the group and learning process. R. Hughes is a former professor in the US Air Force Academy.

Title: Interactive Multimedia: Cost Benefit Analysis Issues

Author: *John J. Hirschbuhl*, Assistant to the President, Information Services, The University of Akron

Illustration by case studies of cost-benefit analysis and positive ROI for networked multimedia in corporate environments. Surprising results have been achieved. For example, the US Institute for Defense Analysis, IBM, and American Airlines indicate that "computer-based multimedia produced a savings of 68% over conventional classroom training" (p. 4).

Innovative Technologies

Title: Automated Speech Technologies: Implications for Training and Education

Authors: *Lyn Gubser*, President, American Insights, Inc., and *Thomas H. Held*, Director Multimedia, Marketing and Product Development, Cubic Applications, Inc.

Review of work at leading laboratories in language instruction and translation, natural language recognition systems and text-to-speech (TTS) systems. Describes the state of the art in Automated Speech Technologies (AST). This is potentially useful in transcription of verbal protocols in full motion simulator sessions testing systems knowledge.

Title: On-Line Dissemination of Expert Knowledge on the Web

Authors: *Dustin Huntington*, EXSYS Inc., and *Elias M. Awad*, McIntire School of Commerce, University of Virginia

Leading expert systems company EXSYS presents their approach to capturing and making accessible, expert knowledge. The system asks the user focused relevant questions and comes to conclusions about the state if their knowledge based on the answers. Users are allowed to ask questions in order to expose the knowledge and inference structures of the expert knowledge representation. Provides explanation and recommendations. Expert knowledge is built using expert knowledge development tools that are files containing decision-making knowledge expressed as rules or facts.

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